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VOLUME VI.

SIXTH SESSION, 1889-90.

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Dufferin Bridge over the Ganges at Benares. The New Bridge of the London, Chatham, and Dover Railway Company over the Thames at Blackfriars. The Barry Dock Works, including the Hydraulic Machinery and the Mode of Tipping Coal. Concrete Quarters for Native Clerks, Guards, and Menial Staff on Indian Railways, etc. The Reclamation of Lake Abaukir. On the Action of Quicksands. The Calliope Graving Dock, Auckland, N.Z. Artesian Wells in South Lincolnshire. On the Probable Errors of Surveying by Vertical Angles. Wire Ropes. Notes on a Short Method of Distributing Triangulation Errors. The Deflection of Spiral Springs.

TRANSACTIONS OF THE CIVIL AND MECHANICAL ENGINEERS' SOCIETY, Session 1888–89, London.—Notes on the Oroya Railway in Peru. Cost of Executing some Classes of Engineering Work. Boring for Petroleum in Galicia, Austria. Inspection and Cleansing of Domestic Drainage. The Compression Members of Bridges. Liquid Fuel. The Newmarket Waterworks. The Roadstones of Somerset and Wilts. Water Supply for Small Towns and Villages.

ENGINEERING ASSOCIATION OF NEW SOUTH WALES, *Vol.* I., 1885-6.—The Treatment of Copper Ores by the Manhes Process. Manufacture of Bread by the Dathis Process. The Van Rysselberghe System of Simultaneous Telegraphy and Telephony. Healthy Dwellings. Compressed Air and its Applications. On the Construction of Breakwaters and Training Jetties. On the use of Concentrated Solutions of Soda for Generating Steam. The Mechanics of Agriculture. The Metallic Arch. The Manufacture of Ice by the Beth Process. Economy in Steam Navigation. Notes on Portland Cement. *Vol.* II., 1886-7.—Some Remarks on Combustion. Electric Lighting. The Adhesion of Cement and of various Cement Mortars to Bricks. On the Application of the Converging Jetty System. The Sanitary Aspect of the Site of the Metropolis and its Environs. Ocean Jetty. Progress of Steam Navigation. On Railway Brakes. *Vol.* III., 1887-8.—Shone's Hydro-pneumatic System of Drainage. The Hydro-pneumatic and Hydraulic System of Sewerage. Apparatus for obtaining Fresh Water for Ships' use. On our Harbour Steamers. Notes on some Mechanical Aspects of Metalliferous Mining in Austrailia. A Description of a Triple-effet Apparatus. The Atlas Engineering Co.'s Hydraulic Pontoon Dock. Some Remarks on Combustion.

TRANSACTIONS OF THE INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND, *Vol.* XXXII., 1888-9, Glasgow.—The Horse-Power of Marine Engines. The Manufacture of the Girders used in the Forth Bridge. The Prevention of Smoke from the Chimneys of Boiler Furnaces. Some Notes on Chimney Draught and Forced Combustion. The Joy Valve Gear and its Results. The Designing of Continuous Current Dynamo Machines. Notes on some recent Steam Engine Trials. On Compound Marine Boilers. On Special Apparatus for the Working of Sails on board Sailing Ships. On the Stability, etc., of Oil-Carrying Steamers. On Dredging and Dredging Appliances. On Evaporation, etc.

GIORNALE DEL GENIO CIVILE ROMA, Eleven *Parts*.—Several interesting Papers on Civil Engineering and Public Works.

JOURNAL OF THE IRON AND STEEL INSTITUTE, 1889, *No.* 1, London.—President's Address. On Alloys of Nickel and Silver. On the Manufacture of Basic Open-Hearth Steel. On the Progress made in the German Iron Industry since 1880. On the Influence of Copper on the Tensile Strength of Steel. On Universal Rolling Mills for the Rolling of Girder and Cruciform Sections. On the Application of Thermal Chemistry to Metallurgical Reactions. On the Thomasset Testing Machine, etc. *Part* II.—Recep-

tion of the Institute at Paris. President's Address. Notes on the Iron and Steel Manufacture in France, as illustrated by the French Exhibits at Paris. On the Proposed Channel Bridge. On Gaseous Fuel. On the Thomson Electric Welding Process. On Alloys of Iron and Silicon. On a new Form of Siemen's Furnace. On the Robert-Bessemer Steel Process. Etc.

JUNIOR ENGINEERING SOCIETY, October, 1889, London.—Presidential Address on Mechanical Engineering in Electrical Industries, by Prof. John Perry. *Pamphlets.*—Manufacture of Iron. Steam Engine Economy. Relation of Chemistry to Engineering. An Engineer's Education. The Use of Theory. Injectors.

TRANSACTIONS OF THE LIVERPOOL ENGINEERING SOCIETY, *Vol.* IX., Session XIV., 1888, Liverpool.—Recent Experiments on Iron and Steel and Riveted Joints. Flood Gates and Weirs on the River Weaver. Filtration of Sewage. Steam Boiler Explosions. Air Brakes. *Vol.* X., Session XV., 1889.—President's Inaugural Address. The Laying of Large Mains. The Advantage to the Civil Engineer of a Study of Geology. Stowing and Lowering of Ship's Lifeboats. The Salt Water Supply to the Public Baths, Bootle. Application of Atmospheric Air to produce Motive Power. Steel in the Hands of the Naval Architect, and Discussion. The Construction of Small Breakwaters and the Silting they give rise to, and Discussion. The Relative Advantages of Steel and Iron for Engine Shafts. Is there any Fibre or Grain in Iron? Some Remarks on a Steamship Performance Diagram. Some Causes of the Crystallization of Iron. The Purification of Water and Sewage by the Magnetic Spongy Carbon Process.

JOURNAL OF THE LIVERPOOL POLYTECHNIC SOCIETY, Session LII., 1889, Liverpool.—Short History of Basic Slag and its Utility as a Fertilizer. Crude Hydrocarbon Liquids as Heating and Lighting Agents. Ventilation by Gas. Hydraulic Buffers. Steam Generation by Gas Fuel. Our Naval and Military Home Coast Defences. Method of Estimating the Weight of Minute Quantities of Gold.

TRANSACTIONS OF THE MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS, *Vol.* XII., *Part* 104, July 1889, Barnsley.—On an Outburst of Gas at the Monk Bretton Colliery, near Barnsley, etc. Two *Parts* not numbered.—Discussion on Outburst of Gas, Monk Bretton Colliery, by Mr. Marshall. Report on an Outburst of Gas in the Haigh Moor Seam at Whitwood Collieries. An Outburst of Gas at Houghton Main Colliery, with discussion. Overwinding and its Prevention. An Apparatus for the Prevention of Overwinding. Notes on the Medium Fan. Geology of the Southern portion of the Yorkshire Coal-field. Coal Getting by Machinery.

PROCEEDINGS OF THE INSTITUTION OF MECHANICAL ENGINEERS, May 1889, *No.* 2, London.—Address by the President. Research Committee on Marine Engine Trials. Description of an Apparatus for Drying in Vacuum. *No.* 3.—Paris Meeting. Description of the Lifts in the Eiffel Tower, The Ether-Pressure Theory of Thermodynamics applied to Steam. The Rationalization of Regnault's Experiments in Steam. On Warp Weaving and Knitting without Weft. On Gas Engines, with Description of the Simplex Engine. Excursions. Etc. *No.* 4, October, 1889.—On the Results of Blast-Furnace Practice with Lime instead of Limestone as Flux. Description of a Rotary Machine for Making Block Bottomed Paper Bags. Further Experiments on Condensation and Re-evaporation of Steam in a Jacketed Cylinder. First Report of the Research Committee on the Value of the Steam Jacket. *No.* 1, January, 1890.—On the Compounding of Locomotives of the Cape Government Railways. On the Mechanical Appliances employed in the Manufacture and Storage of Oxygen.

MANCHESTER ASSOCIATION OF ENGINEERS.—February and March Meetings, 1889. The Loom: Its History, Use, and Construction. Automatic Sprinklers.

TRANSACTIONS OF THE INSTITUTION OF NAVAL ARCHITECTS, *Vol.* XXX., 1889, London.—On the Comparative Merits of Deep Keel and Centreboard Yachts for Racing Purposes. The River Clyde. Copper Steam Pipes for Modern High-Pressure Engines. On the Course of Instruction in Naval Architecture at Glasgow University. The First Century of the Marine Engine. Steam Trials of the Royal Italian Ironclad "Lepanto." The possible Effect of high Explosives on future Designs for War Ships. On the Designs for the new Battle Ships. The Protection of Buoyancy and Stability of Ships. The Protection of Merchant Steamers in time of War. The Italian Cruiser "Piemonte." Water-tube Boilers for War Vessels. On Experiments in endeavouring to burst a Boiler Shell made to Admiralty Scantlings. The Ether-Pressure Theory of Thermodynamics applied to Steam. Marine Boiler Incrustations and their Formation. An Apparatus for providing a steady Platform for Guns, etc., at Sea. The Corrosion and Fouling of Steel and Iron Ships. On the Part played in the Operations of Propulsion by Differences in Fluid Pressure. Remarks on Prof. Greenhill's Theory of the Screw Propeller. On the Connection between the Curve of Stability and the Metacentric Curve or Locus of Pro-metacentres. Details relating to the Correction of Compass Errors in Iron Vessels. On Boat Lowering and Disengaging.

PROCEEDINGS OF THE PHILOSOPHICAL SOCIETY OF GLASGOW, *Vol.* XX.—President's Address. Sanitary and Social Problems. Rotifer as a Parasite or Tube-Dweller. The Eastman Stripping Film and Roller Slide. The Movements of the Joints of the Knuckles and Balls of the Toes. The Training of Architects. Fisheries in Relation to General Civilisation and Progress. Primitive Aryan Civilisation. On the Detection of Mural Pores in the Genus Alveolites. Multiplex Telephony on Long Lines. Agricultural Education in this Country and Abroad. Electro-Magnetic Method of Measuring the Magnetic Constants of the Earth's Field. On Present Tendencies in Classical Studies. Land Ownership in Scotland. A Scheme of Cremation suited to the Requirements of Glasgow. On the Acoustics of Musical Sounds. On Mutual Gables. Exclusion from Day Schools of Children Coming from Families Affected with Contagious Diseases. The Wiring of Buildings for Electric Light. Chili: its Present Position and Future Prospects. Remarks on Bi-Metallism. State Purchase of Land in Ireland. The Science of Ventilation as Applied to Inhabited Interiors. On House Drains without Ventilation. Scheme for the Collection, Treatment, and Disposal of the Sewage of Glasgow.

PROCEEDINGS OF THE SOUTH WALES INSTITUTE OF ENGINEERS, *Vol.* XVI., *No.* 4, July, 1889, Swansea.—Adjourned Discussion on the Hydro-Dynamic Pump. Adjourned Discussion on the Application of Electricity to Underground Haulage. Discussion on Apparatus for Automatically Controlling Bessemer Steel Converters and Centre Cranes. Metallic Sleepers for Permanent Way, and Discussion. Outbursts of Gas in Aberaman Colliery, and Discussion. An Electric Miner's Safety Lamp. Sinking Appliances at Llanbradach. *No.* 5., Swansea, 1889.—Adjourned Discussion on Endless Rope Haulage. Discussion on Metallic Sleepers for Permanent Way. Adjourned Discussion on Outbursts of Gas at Aberaman Colliery. Discussion on Sinking Appliances at Llanbradach. On Wire Ropes. *No.* 6.—Discussion on Endless Rope Haulage. Wire Ropes. Large Incandescent Electric Lamps *versus* Arc Lamps.

TRANSACTIONS OF THE SOCIETY OF ENGINEERS for 1888, London.—Effect of Sea Water on Portland Cement. Wimbledon Main Drainage and Sewage Disposal Works. Filtration by Machinery. Acton Main Drainage Works. Light Railways. Practice of Foundry Work. High Pressure Steam and Steam Engine Efficiency.

PROCEEDINGS OF THE UNITED STATES NAVAL INSTITUTE, *Vol.* XV., *No.* 3, 1889, Annapolis, M.D.—Quick's Patent Perforated Cake-Powder for Ordnance. The Homestead Steel Works. Shipbuilding and its Interests on the Pacific Coast. The Naval Ordnance Proving Ground. Gun-Cotton: Its History, Manufacture, and Use. Electricity on board Warships. Notes on the Literature of Explosives. *No.* 4.—Description of the Works of the Bethlehem Iron Co. Our Future Navy. Steam Trials of the "Lepanto." Notes of the Management of Boats in Surf. Etc. *Vol.* XVI., *No.* 1, 1890.—Naval Administration in Alaska. Powder in Guns. Notes on the Literature of Explosives. Fleet Tactics. Armour for Ships. Antifouling Compositions. Department of Discipline. Comparison of Indications of Testing Machines with those of Standard. Ballistic Photographic Experiments. *No.* 2, 1890.—Report of Policy Board.

ANNUAL REPORT OF THE CHIEF OF THE UNITED STATES OF AMERICA BUREAU OF STEAM ENGINEERING FOR 1889. Washington.

PUBLICATIONS RECEIVED TO DATE, CURRENT NUMBERS OF WHICH LIE ON THE TABLES IN THE READING ROOM:

Electrical Engineer, London.
Electrical Review, London.
Engineering, London.
Indian Engineer, Calcutta, British India.
Indian Engineering, Calcutta, British India.
Industries, London.
Inventions, London.
Iron, London.
Iron and Coal Trades Review, London.
Marine Engineer, London.
Mechanical World, Manchester.
Shipping World, London.
Stahl und Eisen, Düsseldorf.
The Engineer, London.
The Practical Engineer, Manchester.
The Steamship, Leith.

LIST OF OFFICERS.

SIXTH SESSION 1889-90.

President:—F. C. MARSHALL.

Past-Presidents:

W. BOYD. W. THEO. DOXFORD.

Vice-Presidents:

SIR BENJAMIN C. BROWNE.
JOHN DICKINSON.
SIR WILLIAM GRAY.
J. P. HALL.
ARTHUR LAING.
H. MACOLL.
H. F. SWAN.
ROBERT THOMPSON.
R. L. WEIGHTON.

Honorary Treasurer:—B. G. NICHOL.

Councilmen:

W. J. BONE.
H. CHARLTON.
J. R. FOTHERGILL.
JOHN GRAVELL.
W. KILVINGTON.
THOS. MILLAR.
JAMES PATTERSON.
JOHN PRICE.
JAMES READHEAD.
L. RUSDEN.
A. SCHOLEFIELD.
G. W. SIVEWRIGHT.
J. C. STIRZAKER.
ALEX. TAYLOR.
P. WATTS.

Assistant Librarian:—H. S. WALLACE.

Secretary and Treasurer:—J. DUCKITT.

Offices of Institution:

4, St. Nicholas' Buildings West, Newcastle-upon-Tyne.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

List of Members, July, 1890.

EXPLANATION.

(A.) Agent and Accountant.
(C. E.) Civil Engineer.
(D) Draughtsman.
(E.) Engineer and Boilermaker.
(F. M.) Forge Master.
(I. & S. M.) Iron and Steel Merchants and Manufacturers.
(N. A.) Naval Architect.
(R. M.) Rope Manufacturer.
(S.) Shipbuilder.
(S. O.) Ship Owner.
(SUR.) Engineer and Ship Surveyor.

HONORARY MEMBERS.

ELECTED.

The Right Hon. Lord Armstrong, C.B., LL.D., F.R.S., Cragside, Rothbury ... ... Nov. 1884
The Right Honourable the Earl of Ravensworth, Ravensworth Castle, near Gateshead-on-Tyne... ... ... Nov. 1884
W. H. White, Esq., The Admiralty, Whitehall, London ... ... (N A) Nov. 1884

LIFE MEMBERS.

Fox, Samson, Messrs. The Leeds Forge Co., Leeds ... ... (E) Dec. 1887
Halley, David, Messrs. Burmeister & Wains, Maskin-og Skibsbyggeri, Copenhagen, Denmark... ... ... (E) Feb. 1887
Macoll, H., 5, Belvedere Road, Sunderland ... ... (S) Nov. 1884
Pascoe, J. R., Tyrmont, Woodford, Essex ... ... (S) Dec. 1889
Spence, W. G., Messrs. Gourlay, Bros., & Co., Engineers and Shipbuilders, Dundee ... ... (E) Nov. 1884

LIFE ASSOCIATE.

Eccles, Edward, G, Exchange Buildings, King Street, Newcastle-on-Tyne... ... ... (S O) Oct. 1887

MEMBERS.

A.

Aberg, Henning, Stora Warfoet, Stockholm, Sweden ... ... (E) Oct. 1888
Abey, Henry, Fairfield, York Road, West Hartlepool ... ... (E) Jan. 1889
Adamson, Alex., c/o Messrs. Naval Construction and Armaments Co., Barrow-in-Furness ... ... (S) Nov. 1885
Ahlbom, C., 11, Sidney Grove, Arthur's Hill, Newcastle-on-Tyne ... (E) Nov. 1884
Aitchison, Jas., Hylton, Sunderland ... ... (S) Nov. 1884

ELECTED

Alchin, A. H., 89, Wood Lane, Shepherd's Bush, London ... ... (E) Jan. 1885
Allan, David T., c/o Messrs. Black, Hawthorn, & Co., Gateshead-on-Tyne ... ... (E) May 1889
Allan, Jas. McNeal, 5, Warwick Street, Heaton, Newcastle-on-Tyne (E) Dec. 1886
Allardes, Wm., Greenville Terrace, Bloomfield, Belfast ... ... (E) Nov. 1884
Anderson, J., c/o Messrs. Wigham Richardson & Co., Neptune Works, Walker-on-Tyne ... ... Nov. 1884
Andrew, D., 33, Osborne Road, Jesmond, Newcastle-on-Tyne ...(SUR) Jan. 1885
Andrews, Jas., Drawing Office, Messrs. Naval Construction and Armaments Co., Barrow-in-Furness ... ... (E) Nov. 1884
Anthony, Jas., 6, Northumberland Square, North Shields... ... (S) Oct. 1886
Archbold, Joseph G., c/o Messrs. Blyth Dry Dock Co., Blyth ... (E) Jan. 1889
Armstrong, G. S., 37, Warwick Street, Heaton, Newcastle-on-Tyne (E) Nov. 1884
Armstrong, Robert B., East Boldon, Sunderland .. .. (E) Oct. 1887
Arnison, Geo., Jun., 61, Fawcett Street, Sunderland ... ...(N A) Nov. 1884
Ash, Mortimer W. ... ... (E) Feb. 1887
Austin, S. P., Wear Dockyard, Sunderland ... ... (S) Nov. 1884
Austin, W. R., Lloyd's Register of Shipping, Royal Exchange, Middlesbrough ... ... (E) Oct. 1888

B.

Bailey, James, 3, South Avenue, Ryton-on-Tyne ... ... (E) Nov. 1884
Baines, Geo. Henry, Messrs. Central Marine Engineering Co., West Hartlepool ... ... (E) Oct. 1888
Baird, Robert, 13, Hylton Terrace, North Shields ... ... (E) Jan. 1890
Barclay, James, Lloyd's Register of Shipping, Newcastle-on-Tyne...(SUR) Nov. 1888
Barley, C. J. ... ... (E) { Graduate, Feb. 1885 / Member, Dec. 1886 }
Barnett, James Rennie, Lilybank House, Johnston, N.B. ... ... (S) Oct. 1889
Barron, T. G., Fern Villas, Elwick Road, West Hartlepool ... (E) Oct. 1888
Bastow, W. W., 112, Scarborough Street, West Hartlepool ... (S) Dec. 1889
Batliboi, Jehangir Framji, Bombay, British India (temporary address: 1, Olive Street, Sunderland) ... ... (E) Dec. 1888
Batey, John Thomas, 25, Harrison Place, Newcastle-on-Tyne ... (S) Nov. 1885
Baxter, J., 9, Warwick Street, Heaton, Newcastle-on-Tyne ... (E) Nov. 1884
Beadon, D. C., 29, Beverley Terrace, Cullercoats ... ... (E) Jan. 1885
Beardmore, William, Messrs. Wm. Beardmore & Co., Parkhead Forge, Glasgow ... ... (I & S M) Oct. 1889
Bell, James, 29, Croft Terrace, Jarrow-on-Tyne ... ... (E) Feb. 1887
Bell, William, Rosehill Terrace, Rosehill, Wallsend-on-Tyne ... (E) Nov. 1888
Bergström, Gus., Poplar Grove, Hart Road, West Hartlepool ... (N A) Mar. 1886
Berkley, A. B., Grange Villa, Jarrow-on-Tyne ... ... (E) Mar. 1887
Berkley, William, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne ... ... (E) Oct. 1889
Bindesböll, S. C. W., c/o Messrs. Raylton Dixon & Co., Middlesbrough ... ... (S) Nov. 1884
Bittleston, W. H., 9, Crooms Hill, Greenwich, S.E.... ... ... (S) May 1885

ELECTED.

Black, Jas., Portobello Foundry, Sunderland ... ... (E) Jan. 1885
Black, J., c/o Messrs. J. Merryweather & Co., West Hartlepool ... (E) Nov. 1888
Black, Wm., Messrs. Black, Hawthorn, & Co., Gateshead-on-Tyne (E) Jan. 1885
Blakston, J. W., 5, Douro Terrace, Monkwearmouth, Sunderland... (S) Jan. 1886
Blechynden, Alfred, 12, Cavendish Park, Barrow-in-Furness ... (E) Oct. 1885
Blenkinsop, John N., 38, Ashbornham Grove, Greenwich, S.E. ... (E) Oct. 1885
Blumer, Wm. Riversley, Millum Terrace, Monkwearmouth, Sunderland ... ... (S) Dec. 1886
Boddy, John, 96, Dock Street, Newport, Mon. ... ... (E) Dec. 1888
Bodin, Lauritz M., 27, Argyle Square, Sunderland ... ... (E) Dec. 1889
Bond, C. P. W., 27, Leadenhall Street, London, E.C. ... ... (E) Nov. 1888
Bone, W. J., 61, Linskill Terrace, North Shields ... ... (S) Dec. 1884
Bonneyman, James Smith, 13, Ryder Street, Canton, Cardiff ... (E) Nov. 1889
Boolds, Jas. H., c/o Messrs. Raylton Dixon & Co., Middlesborough (S) Oct. 1886
Booth, Arthur Spence, 77, Thornton Street, West Hartlepool ... (E) Oct. 1889
Borowski, G., Government Dock Yard, Cherson's Depart., Nicolajew, Russia ... ... (E) Oct. 1885
Boyd, Wm., North House, Long Benton, Newcastle-on-Tyne ... (E) Nov. 1884
Bramwell, Balfour, 2, Beverley Terrace, Cullercoats (E) {Graduate, Nov. 1886 / Member, Nov. 1887}
Brankston, R. T. ... ... (E) Nov. 1884
Brock, John, 20, Azalea Terrace South, Sunderland ... ... (E) Nov. 1885
Brown, George, Messrs. C. S. Swan, Hunter & Co., Wallsend ... (S) Dec. 1889
Brown, Eugene, 10, Boldon Terrace, Jesmond, Newcastle-on-Tyne (E) Feb. 1886
Brown, Robson, Belle Vue Terrace, Tyne Dock ... ... (E) Nov. 1889
Brown, T. R., 110, Roker Avenue, Sunderland ... (E) {Graduate, May 1885 / Member, Oct. 1886}
Brown, William, H.M.S. Barham, Royal Dockyard, Portsmouth ... (E) April 1887
Brown, E. D., c/o Tees Conservancy Commissioners, Middlesborough (E) Nov. 1888
Browne, Sir B. C., Westacres, Benwell, near Newcastle-on-Tyne (C E) Jan. 1885
Buchanan, A., Michaelson Villa, Barrow-in-Furness ... ... (S) Nov. 1884
Buchanan, John H., Lloyd's Register of Shipping, Royal Exchange, Middlesborough ... ...(SUR) Oct. 1888
Buchanan, Charles, Lloyd's Register of Shipping, 3, St. Nicholas' Buildings, Newcastle-on-Tyne ... ...(SUR) April 1889
Buckland, H. B., Hamburg Chambers, Quayside, Newcastle-on-Tyne (E) Nov. 1885
Bulmer, John, 1, Graingerville North, Newcastle-on-Tyne ... (E) Mar. 1886
Burdon. J. G., 20, Archbold Terrace, Newcastle-on-Tyne ... ... (E) Nov. 1884
Burns, J., 3, Kaiser Terrace, West Hartlepool ... ... Nov. 1884
Butterfield, George, 30, John Candlish Road, Millfield, Sunderland Nov. 1884

C.

Cama, Nusserwanji Bomanji, 17, Girgaum Back Road, Bombay, British India ... ... (E) Dec. 1888
Campbell, James J., c/o Messrs. J. & E. Hall & Co., Dartford, Kent (E) Oct. 1888
Cannell, Frank, Messrs. H. Parry & Son, Lisbon ... ... (E & S) Nov. 1887
Carr, J. W. ... ... (E) Feb. 1885

ELECTED.

Carrick, H., Holly House, Gateshead-on-Tyne ... ... (E) Nov. 1884
Carstons, Samuel, 26, 2 Sel. Herlief Trollugode, Copenhagen ... (S) Dec. 1887
Carter, G. J., Elswick Shipyard, Newcastle-on-Tyne ... ... (S) Dec. 1886
Carter, Thos., 49, North Bridge Street, Monkwearmouth, Sunderland (E) Nov. 1884
Casebourne, Charles Baston, Greatham House, Greatham, near West Hartlepool ... ... (E) Dec. 1889
Cay, Arthur, Westoe, South Shields ... ... (E) Nov. 1884
Ceuvel, John L., Kadyk, Amsterdam ... ... (E) Mar. 1886
Chapman, Abel, Capt., Belle Vue, Low Fell, Gateshead-on-Tyne... (E) Nov. 1884
Chapman, Alfred C., 2, St. Nicholas' Buildings, Newcastle-on-Tyne (E) Oct. 1888
Chapman, Hedley, 147, Park Road, Newcastle-on-Tyne ... ... (E) Feb. 1886
Charlton, Henry, 1, Millfield Terrace, Gateshead-on-Tyne... ... (E) Nov. 1884
Charlton, R. B., Jun., Manors Railway Station Works, Newcastle-on-Tyne ... ... (E) Nov. 1884
Charlton, T., 25, Lincoln Street, Gateshead-on-Tyne ... ... (E) Nov. 1884
Christie, C. A., 4, Woodside, Tynemouth ... ... (E) Nov. 1884
Christie, C. J. D., Neptune Works, Walker-on-Tyne ... ... (S) Nov. 1884
Christie, J. D., 4, Colbeck Terrace, Tynemouth ... ... (S) Nov. 1884
Churchill, James Dixon, 23, Leadenhall Street, London, E.C. ... (E) Oct. 1889
Clark, Geo., Southwick Engine Works, Sunderland ... ... (E) Nov. 1884
Clark, George, Jun., Southwick Engine Works, Sunderland ... (E) Feb. 1888
Clark, Henry, Southwick Engine Works, Sunderland ... ... (E) Oct. 1887
Clarke, Thos., 82, Rye Hill, Newcastle-on-Tyne ... ... (E) Nov. 1884
Cochrane, James, 12, Broomhill Avenue, Partick, Glasgow ... (E) Nov. 1888
Connell, Charles, 8, Balsbagran Terrace, Partick, Glasgow ... (S) Nov. 1888
Conning, Alfred C., Dunston Iron & Steel Works, Gateshead-on-Tyne (F M) May 1885
Conràdi, Carl, 2, Annfield, Leith ... ... (E) Nov. 1884
Cooper, Nusserwanji Naoroji, Tuths Agari, Chawpati, Malabar Hill, Bombay, India ... ... (E) Oct. 1889
Cooper, William, Baltic Chambers, Quayside, Newcastle-on-Tyne (E) Feb. 1888
Coote, Arthur, Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne ... ... (S) Nov. 1884
Cornforth, J., Messrs. Gladstone & Cornforth, Church Street, West Hartlepool ... ... (E) Oct. 1888
Cornish, H. P., Lloyd's Register of Shipping, 2, White Lion Court, Cornhill, London, or 2, Lawn Road, Hamstead, London, N.W. (E) Oct. 1888
Courtier-Dutton, W. T., Lloyd's Register of Shipping, 3, St. Nicholas' Buildings, Newcastle-on-Tyne ... ... (S) April 1890
Cowan, M., 22, Clarendon Terrace, South Shields ... ... (S) Mar. 1889
Cowens, William Edward, c/o Messrs. John Abbot & Co., Gateshead-on-Tyne ... ... (E) Dec. 1889
Craggs, Ernest H., Messrs. R. Craggs & Sons, Middlesborough ... (S) Oct. 1888
Crawford, Jas., 9, Custom House Court, Quayside, Newcastle-on-Tyne (SUR) Nov. 1886
Crawford, John P., 1, St. Vincent Street, Sunderland ... ... (E) May 1889
Crawford, W. A. F., c/o Messrs. Rayne & Crawford, 31, Close, Newcastle-on-Tyne... ... ... (E) Nov. 1884
Cross, Wm., 4, Fenham Terrace, Newcastle-on-Tyne ... ... (E) Mar. 1886

ELECTED.

Cruddas, W. D., Messrs. Sir W. G. Armstrong, Mitchell, & Co., Elswick, Newcastle-on-Tyne ... ... (E) Dec. 1884
Cummins, W. R., 40, Perth Road, Dundee ... ... (E) Nov. 1884
Curwen, Henry R., c/o Messrs. Palmer's Iron and Shipbuilding Co., Jarrow-on-Tyne ... ... (S) Graduate, Feb. 1886; Member, Oct. 1887

D.

Dalrymple, Wm., 8, Aberdere Terrace, South Shields ... ... (E) Dec. 1886
Darling, W. J., Lloyd's Register of Shipping, Leith ... ... (S) April 1887
Darney, John, c/o Messrs. Short Bros., Pallion, Sunderland ... (S) Nov. 1884
Davie. Albert, c/o Messrs. W. Denny & Bros., Leven Shipyard, Dumbarton, N.B. ... ... (E) Graduate, Feb. 1886; Member, Oct. 1887
Davison, A. J., Rosedale, Wallwood Road, Leytonstone, Essex ... (E) Oct. 1888
Dawe, Charles, H.M.S. "Katomba," Royal Navy ... ... (E) Mar. 1890
Dempsy, S. ... ... (S) Nov. 1884
Dick, Francis, 6, Gladstone Street, Sunderland ... ... (E) Nov. 1885
Dickinson, F. T., Park House, Sunderland ... ... (E) Graduate, May 1885; Member, Oct. 1886
Dickinson, James, Park House, Sunderland ... ... (E) Nov. 1884
Dickinson, John, Park House, Sunderland ... ... (E) Nov. 1884
Dickinson, W., Park House, Sunderland ... ... (E) Nov. 1884
Dickinson, R. E., c/o Messrs. Palmer's Iron & Shipbuilding Co., Jarrow-on-Tyne ... ... (E) April 1889
Dixon-Brown, L. D., Unthank Hall, Haltwhistle ... ... (S) Nov. 1886
Dixon, Sir Raylton, Cleveland Shipyard, Middlesborough ... (S) Feb. 1888
Dobson, William, Shipbuilder, Walker-on-Tyne ... ... (S) Nov. 1888
Donald, James, 48, St. Luke's Terrace, Pallion, Sunderland ... (S) Nov. 1884
Donovan, J. W., 4, Elizabeth Street, Newcastle Road, Sunderland (E) April 1885
Douglas, John F., c/o Messrs. Ramage & Ferguson, Leith ... ... (E) Jan. 1888
Dowsen, Chas., 8, Croft Terrace, Jarrow-on-Tyne ... ... (E) Dec. 1885
Doxford, Charles D., Bainbridge Holme, Tunstall Road, Sunderland (S) Nov. 1884
Doxford, R. P., Pallion Engine Works, Sunderland ... ... (E) Nov. 1884
Doxford, W. T., Pallion Shipyard, Sunderland ... ... (S) Nov. 1884
Drakenberg, J. A., 73, Mybrogatan, Stockholm, Sweden ... ... (E) Feb. 1886
Duckitt, Jno., 4, St. Nicholas' Buildings West, Newcastle-on-Tyne (E) Nov. 1884
Dudgeon, F. S., 112, Fenchurch Street, London, E.C. ... ... (E) Feb. 1885
Dunlop, William, 31, Hartington Street, Barrow-in-Furness ... (E) Mar. 1888
Dykes, James, 78, Dilston Road, Newcastle-on-Tyne ... ... (E) May 1885
Dykes, John, Lloyd's Register of Shipping, Barrow-in-Furness ...(SUR) Oct. 1889

E.

Eckmann, John, Sunderland Engine Works, South Docks, Sunderland (E) May 1885
Edmiston, Jas. B., Ivy Cottage, Highfield Road, Walton, Liverpool (E) Nov. 1886
Edwards, James Henry, Byethorn, Corbridge ... ... (S) Nov. 1889
Eeles, Robert, Messrs. Eeles & Dryden, 4, Quayside, Newcastle-on-Tyne (E) Apr. 1889
Elliott, Consitt, Bedford Villa, Burnt Mill, Essex ... ... (E) May 1885
Eltringham, J., c/o Messrs. J. T. Eltringham & Co., South Shields (E) May 1889

ELECTED.

Eltringham. Joseph T., Stone Quay, South Shields ... ... (S & B B) Oct. 1889
Engelbach, Herbert R., c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Elswick Works, Newcastle-on-Tyne ... ... (E) Nov. 1884
English, E. Harold, Messrs. Westgarth, English, & Co., Middlesbro' (E) Feb. 1889
Errington, Joseph R., 51, Dock Street East, Sunderland ... ... (E) Jan. 1888
Eshelby, William, 1, Lax Terrace, Stockton-on-Tees ... ... (E) Feb. 1888
Evans, William, 2, Salisbury Street, Sunderland ... ... (E) Nov. 1889
Evers, G., Lubeck, Germany ... ... (S) Nov. 1884

F.

Fairman, A. E., Helensburgh, Scotland ... ... (N A) Oct. 1886
Farina, A. J., Oakwood House, Westmorland Road, Newcastle-on-Tyne (E) Nov. 1884
Faruffini, Capt. M. C., c/o Connitato Pei Designa delle Navi Ministero dilla Marina, Rome, Italy ... ... (N A) Dec. 1888
Feldtmann, H., Bergen, Norway ... ... (E) Jan. 1889
Findlay, John Taylor, 11, Nelson Street, Sunderland ... ... (S) Feb. 1890
Firth, H. Branson, Thrift House, Ecclesall, Sheffield ... ... (S M) Oct. 1888
Fleming, Charles Edward, 71, Elswick Road, Newcastle-on-Tyne .. (E) Nov. 1884
Fletcher, James, 6, Radnor Terrace, Dumbarton Road, Glasgow ... (E) Dec. 1885
Fletcher, Robert, Walker Forge, Walker-on-Tyne ... ... (F M) Dec. 1886
Flohr, Justus, 32, Birkencellies, Stettin, Germany ... ... (E) Oct. 1886
Foley, Nelson, Villa Beatrice, Parco Griffeo, Naples, Italy ... (E) Nov. 1884
Forster, C., 6, Ellison Place, Newcastle-on-Tyne ... ... (S) Nov. 1888
Forster, William, c/o Messrs. Dixon & Robson & Co., 25, Mosley Street, Newcastle-on-Tyne ... ... (E) Mar. 1890
Foster, Henry, Newburn Steel Works, Newburn-on-Tyne ... ... (E) April 1885
Fothergill, J. R., 1, Bathgate Terrace, West Hartlepool ... ... (E) Mar. 1886
Fownes, Henry, Tyne Forge, Ouseburn, Newcastle-on-Tyne ... (F M) Nov. 1884
Franki, J. P., c/o Messrs. Morts Dry Dock & Engineering Co., Sydney, N.S.W., Australia ... ... (E) Jan. 1886
Furneaux, J. B., Victoria Engine Works, Gateshead-on-Tyne ... (E) Nov. 1885
Furness, John, c/o Messrs. Stephens & Mawson, Bank Chambers, Quayside, Newcastle-on-Tyne ... ... (E) Nov. 1885
Furse, Fred., c/o Messrs. R. & W. Hawthorn. Leslie, & Co., Shipyard, Hebburn-on-Tyne ... ... (E) April 1887

G.

Gannaway, H. G., 23, Bede Burn Road, Jarrow-on-Tyne ... ... (S) Nov. 1884
Garratt, H. A., 3, Haghenden, Clifton, Bristol ... (E) { Graduate, Nov. 1884 / Member, Nov. 1886 }
Garthwaite, John R., c/o Messrs. R. Ropner & Sons, Stockton-on-Tees (S) May 1889
Gayner, Robt. H., Jun., Beech Holm, Sunderland ... (E) { Graduate, Mar. 1886 / Member, Oct. 1888 }
Geddes, Christopher, c/o Messrs. Leeds Forge Co., Leeds ... ... (E) Oct. 1888
Gibson, H., 6, Dundas Street, Monkwearmouth, Sunderland ... (S) Nov. 1884
Gibson, W. H., 37, Tatham Street, Sunderland ... ... (E) Nov. 1884

Gladstone, Arthur, Messrs. Gladstone & Co., West Hartlepool Rolling Mills, West Hartlepool ... ... (I & S M) Oct. 1888
Glencross, Thos., 11, Ryehill, Newcastle-on-Tyne ... ... (E) Feb. 1885
Glover, Terrot, 6, Azalea Terrace, Sunderland ... ... (E) Mar. 1886
Goddard, George Arthur, 100, Park Crescent, North Shields ... (D) Feb. 1890
Gordon, William James, c/o Messrs. Naval Construction & Armaments Co., Barrow-in-Furness ... ... (E) Oct. 1887
Graham, Edwin, Messrs. Osbourne, Graham, & Co., Hylton, Sunderland (S) Nov. 1884
Graham, Joseph, 13, Whitehall Terrace, Sunderland ... ... Nov. 1884
Graham, T. S., 19, Sea View Terrace, E. Hartlepool ... ... (E) Nov. 1888
Graham, Wm., Ford Lodge, South Hylton, nr. Sunderland ... (S) Nov. 1884
Gravell, John, Custom House Court, Quay, Newcastle-on-Tyne ...(SUR) Nov. 1884
Gray, A., c/o Messrs. R. Stephenson & Co., South Street, Newcastle-on-Tyne ... ... (E) Nov. 1888
Gray, George, 13, Harold Street, Sunderland ... ... (E) Feb. 1888
Gray, Harry, 12, Grosvenor Road, Jesmond, Newcastle-on-Tyne ... (E) Dec. 1885
Gray, Matthew, Messrs. W. Gray & Co., West Hartlepool ... ... (S) Oct. 1888
Gray, Sir William, Messrs. W. Gray & Co., West Hartlepool (S & E) Oct. 1888
Green, W. G., c/o Messrs. Palmer's Iron and Shipbuilding Co., Jarrow-on-Tyne ... ... (E) Nov. 1884
Green, William, c/o Messrs. Naval Construction and Armaments Co., Barrow-in-Furness ... ... (E) Oct. 1885
Grieves, Robert, 38, Linskill Terrace, North Shields (S) { Graduate, Nov. 1884 / Member, Dec. 1886 }
Grimes, Thomas Benjamin, 30, Broughton Road, South Shields ... (E) Mar. 1890
Gulston, A., Clayton Park Lodge, Jesmond, Newcastle-on-Tyne ... (E) Dec. 1888

H.

Hake, G. A., 29, Rothbury Terrace, Heaton, Newcastle-on-Tyne ...(SUR) Oct. 1888
Hall-Brown, E., 15, Moor Terrace, Hartlepool ... ... (E) Nov. 1888
Hall, Edward, Astellos del Navion, Bilbao, Spain ... ... (S) Nov. 1885
Hall, J. Percy, Carville, Laurie Park Road, Sydenham, London, S.C. (E) Oct. 1885
Hall, John W., Abden Shipyard, Kinghorn, N.B. ... ... (S) Oct. 1887
Hamilton, John, 81, Charlotte Street, Carlisle ... ... (E) Nov. 1886
Hamilton, J. H., Engine Works, Sandiacre, near Nottingham ... (E) Nov. 1888
Hamilton, R. R., c/o Messrs. Maudslay, Sons, & Field, Lambeth, London ... ... (E) Nov. 1884
Hansen, F. T., Moss Jernstöberi og Mek Værksted, near Christiania, Norway ... ... (E) Nov. 1884
Harding, J. C., 9, Alderson Street, West Hartlepool ... ... (E) Nov. 1884
Hardwick, T. Norman, 17, Nixon Street, Newcastle-on-Tyne ... (E) Dec. 1888
Hardy, Arthur Francis, c/o Rev. A. Curtis, The Vicarage, White Motley, Essex ... ... (S) Oct. 1887
Harkness, Richard, 9, Meldon Terrace, Heaton, Newcastle-on-Tyne (S) Nov. 1884
Harlow, F., 15, Clayton Park Square, Newcastle-on-Tyne... ... (E) Nov. 1884
Harman, Bruce, 12, Annfield Terrace West, Partick, Glasgow ... (E) Oct. 1886
Harper, J. H., 1, Beaumont Street, North Shields ... ... (E) Jan. 1885

ELECTED

Harrison, Alfred, 13, Nelson Street, Sunderland ... ... (E) Oct. 1889
Harrold, Alexander, 19, Lawton Street, Newcastle-on-Tyne ... (E) Nov. 1884
Harrold, F., 14, Rowell Street, Hartlepool ... ... (E) Nov. 1888
Hartness, J., East Boldon, near Sunderland ... ... (E) Nov. 1884
Harvey, John W. J., 1, Richmond Villa, Chertsey Road, Bristol ... (E) Feb. 1889
Haswell, Robert, 11, Union Street, Hartlepool ... ... (S) Dec. 1888
Havelock, Michael, Commercial Chambers, Side, Newcastle-on-Tyne (E) Dec. 1887
Head, Archibald P., Coatham, Redcar, Yorkshire ... (E) {Graduate, Nov. 1884 / Member, Oct. 1887}
Head, Jeremiah, Queen's Square, Middlesborough-on-Tees ... (I M) Oct. 1889
Headlam, Robert, 5, Edward Street, Stockton-on-Tees ... ... (E) Nov. 1886
Heck, John H., Lloyd's Register of Shipping, Newport, Monmouthshire ... ... (S) Nov. 1885
Helyer, A. J., Germania Werft, Gaarden bei Kiel, Germany ... (S) Oct. 1887
Henderson, George, 54, Westmorland Road, Newcastle-on-Tyne ... (E) Nov. 1884
Henderson, Robert, c/o Messrs. C. S. Swan & Hunter, Wallsend-on-Tyne ... ... (S) Nov. 1884
Hepple, William, Slipway, North Shields ... ... (E & S) Oct. 1885
Hildrey, A. J. ... ... (S) Nov. 1884
Hill, Maxwell, c/o Messrs. Palmer's Iron and Shipbuilding Co., Jarrow-on-Tyne ... ... (S) Nov. 1884
Hill, Maxwell, c/o Messrs. J. & G. Thompson, Clydebank, Glasgow (S) Nov. 1887
Hills, Charles Henry, Anglesey Copper Works, Walker-on-Tyne ... (E) Nov. 1889
Hindson, William, Bensham Lodge, Gateshead-on-Tyne ... ... (E) Nov. 1884
Hines, William, H.M.S. "Karrakatta," Royal Navy ... ... (E) Mar. 1890
Hirst, Richard, 4, Cleveland Road, North Shields ... ... (E) Nov. 1885
Hogg, James, Upper Coach Lane, North Shields ... ... (BF) Nov. 1889
Hök, Wilhelm, Deptford Shipyard, Sunderland ... ... (S) Oct. 1886
Hole, John W., H.M.S. "Whiting," Royal Navy ... ... (E) Mar. 1890
Holmes, John H., Portland Road, Newcastle-on-Tyne ... ... (E) Jan. 1888
Homji, A. C. N., 13, Trinity Street, Dhobie, Talao, India ... ... (E) Nov. 1884
Hooper, Ernest, 23, Whitehall Terrace, Sunderland ... ... (E) Nov. 1885
Hunter, George B., Messrs. C. S. Swan, Hunter, & Co., Wallsend-on-Tyne ... ... (S) Nov. 1884
Hunter, J. W., 9, Alice Street, Sunderland ... ... (E) May 1885
Hunter, Summers, c/o Messrs. N.E. Marine Engineering Co., Wallsend-on-Tyne ... ... (E) Nov. 1885
Hutchinson, C. W., 6, Park Parade, Westmorland Road, Newcastle-on-Tyne ... ... (E) Nov. 1884
Hymers, Richard, 68, Meldon Terrace, Heaton, Newcastle-on-Tyne (E) Mar. 1887

I.

Inglis, John, c/o Messrs. Hawthorn & Co., Leith ... ... (S) April 1887
Inglis, John, Jun., Pointhouse Shipyard, Partick, Glasgow ... (E) Oct. 1886
Irwin, J. H., Sunderland Engine Works, South Docks, Sunderland (E) Nov. 1884
Irwin, Thomas F., 2, Tower Chambers, Old Churchyard, Liverpool ... ... (C E & N A) Mar. 1888

ELECTED.

J.

Jackson, Vincent, 19, Regent Street, Hartlepool ... ... (S) April 1888
Jackson, A., Surveyor's Office, Board of Trade, North Shields ... (E) Nov. 1838
James, M. C., c/o Messrs. Robert Stephenson & Co., Ld., Engineers and Shipbuilders, Hebburn-on-Tyne ... ... (S) Nov. 1884
Jamieson, John, 25, Azalea Terrace South, Sunderland ... ... (E) Nov. 1885
Jobling, J. C., Blackwall Ironworks, Isle of Dogs, London, E. ... (E) Nov. 1884
Jobling, W. J., Queen Street, Newcastle-on-Tyne ... ... (E & S O) Nov. 1884
John, Edmund, Barry Dock, Cardiff ... ... (E) Dec. 1889
Johnson, Johan, Ashmore Street, Sunderland ... ... (S) May 1885
Johnson, T. Allan, 15, Stannington Avenue, Heaton, Newcastle-on-Tyne ... ... (S) Nov. 188
Johnstone, William, Lloyd's Register of Shipping, 2, White Lion Court, Cornhill, London, E.C. ... ... (SUR) Nov. 1884
Joicey, Jacob G., Forth Banks West Factory, Newcastle-on-Tyne (E) Jan. 1889
Jones, Frederick Robert, Sirmoor State, Nahan, Punjaub, India... (E) Oct. 1889
Jones, George, c/o Messrs. W. Gray & Co., West Hartlepool ... (S) Oct. 1888
Jones, Morlais G., 1, Fern Bank, Chester Road, Old Trafford, Manchester ... ... (E) Nov. 1887
Jorgenson, F., Inspector to Austrian Lloyd's, Constantinople ...(SUR) Nov. 1888

K.

Keene, H. R. ... ... (E) { Graduate, May 1885 / Member, April 1887 }
Kellner, T., c/o K.K. Schiffbirn Juginieur Pola, Austria ... ... (N A) Oct. 1887
Key, Alexander, 36A, City Buildings, Old Hall Street, Liverpool (SUR) Nov. 1884
Keydell, Amandus Edmund, Lloyd's Register of Shipping, Dundee (S) April 1890
Kilvington, W., Northumberland Engine Works, Wallsend-on-Tyne (E) Nov. 1884
King, Donald, Engineering Department, Messrs. Martinez, Rivas, and Palmer, Bilbao, Spain ... ... (E) Jan. 1890
Kirkaldy, John, 40, West India Dock Road, London ... ... (E) Nov. 1885
Kirkaldy, William, c/o Messrs. Wigham Richardson & Co., Neptune Works, Walker-on-Tyne ... ... (E) Dec. 1889

L.

Laidley, R. W., 10, Hunter Street, Sydney, New South Wales ... (E) April 1887
Laing, Arthur, Deptford Shipyard, Sunderland ... ... (S) Nov. 1884
Laing, Jas., Jun., Deptford Yard, Sunderland ... ... (S) Nov. 1884
Laing, John, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne ... ... (E) Nov. 1884
Larkin, James, 2, William Black Street, East Jarrow-on-Tyne ... (E) Nov. 1884
Leckie, Andrew, Cambridge Terrace, West Hartlepool ... ...(SUR) Oct. 1888
Leddicoat, Frederick, 5, Cromwell Terrace, Gateshead-on-Tyne ... (E) Oct. 1885
Lewis, Henry W., Llwynynhess, Abercanaid, near Merthyr, Glamorganshire, Wales ... ... (E) Nov. 1885
Lewis, R. A., Newburn Steel Works, Newburn-on-Tyne ... ... (E) Nov. 1884
Liddell, A. B., 10, Buckt Strasse, Vegesack, Germany ... ... (S) Nov. 1884

ELECTED.

Liddell, J., c/o Messrs. Denny & Co., Engine Works, Dumbarton... (E) Nov. 1884
Lindfors, H., P.O. Box, 758, Norwark Comm., U.S. America ... (S) Oct. 1886
Lindfors, Hugo, 16, Alexandersgatan, Helsingfors, Findland ... (S) May 1889
Littleboy, Chas. Wm., 12, Shaftesbury Street, Stockton-on-Tees ... (S) Oct. 1887
Livingston, Thos., Dunedin House, Jarrow-on-Tyne ... ... (S) Nov. 1884
Livingstone, John, 6, Simonside Terrace, Heaton, Newcastle-on-Tyne (E) Nov. 1884
Lohmeyer, H., 43, Crown Street, Newcastle-on-Tyne ... ... (E) Nov. 1884
Long, A. E., 124, Albert Road, Jarrow-on-Tyne ... ... (S) Nov. 1884

M.

Macarthy, Harry, Ashfield House, Newcastle-on-Tyne ... ... (E) Nov. 1888
Maccoy, John, 55, Larkspur Terrace, Newcastle-on-Tyne ... ... (E) Feb. 1886
Mace, W., 253, Albert Road, Jarrow-on-Tyne ... ... (E) Jan. 1886
MacGregor, John, 2, Michaelston Villas, Barrow-in-Furness ... (E) Mar. 1888
MacHaffie, John, 110, Union Street, Schenectudy, New York, U.S. America ... ... (E) Dec. 1885
Macoll, D. C., 14, Connaught Terrace, Jarrow-on-Tyne ... ... (S) Nov. 1884
Manuel, G. W., Eildon, Ravensbourne Park, Catford, London ... (E) Dec. 1885
Marlborough, Richard, 11, Brookland Road, Sunderland ... ... (S) Nov. 1884
Marr, James, 6, Ash Place, Sunderland ... ... (S) Nov. 1884
Marshall, F. C., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne ... ... (E) Nov. 1884
Marshall, Frank T., 38, Percy Gardens, Tynemouth (E) {Graduate, Jan. 1885 / Member, Oct. 1888}
Marshall, R. J., 32, Mariners' Cottages, South Shields ... ... (E) Mar. 1887
Martens, D., 52, Kent Street, Jarrow-on-Tyne ... ... (E) Mar. 1887
Mastaglio, W. D., 11, Tenth Avenue, Heaton, Newcastle-on-Tyne (E) Nov. 1885
Mather, Charles, 6, Kenilworth Road, Newcastle-on-Tyne ... ...(SUR) Oct. 1888
Matheson, William, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne ... ... (S) Dec. 1889
Matthews, A., The Baths, Blyth ... ... (E) Nov. 1884
Matthews, Jas., c/o Messrs. R. & W. Hawthorn, Leslie, & Co., Forth Banks, Newcastle-on-Tyne ... ... (E) Oct. 1886
Maughan, Wm., 15, Addison Road, Heaton, Newcastle-on-Tyne ... (E) Mar. 1887
Mavor, Alfred E., 4, Elmbank Crescent, Glasgow, N.B. ... ... (EE) Feb. 1890
McDougall, Neil, Managing Director British Steam Users' Insurance Society, Ld., 4 & 5, Victoria Buildings, Manchester ... (E) Mar. 1890
McGlashan, Arch., 26, Milton Street, West Hartlepool ... ... (S) Nov. 1885
McIlvenna, J. G., c/o Messrs. The Tyne Pontoon and Dry Docks Co., Wallsend-on-Tyne ... ... (S) Nov. 1884
McIntyre, John, 3, Abbotsford Terrace, Newcastle-on-Tyne ... (S O) Jan. 1885
McKay, Jno., c/o Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne ... ... (E) Nov. 1884
Menzies, Wm., The Side, Newcastle-on-Tyne ... ... (E) Nov. 1884
Messenger, Thomas, 2, Clarence Lawn, Dover, Kent *... ... (E) Mar. 1887
Metcalf, J. C., 4, Azalea Terrace North, Sunderland ... (SUR) Nov. 1884
Metcalfe, C. S., 5, Tunstall Terrace West, Sunderland ... ... (E) Nov. 1884

ELECTED.

Micheli, Pietro, Jun., 5, Via Assarotti, Genoa ... ... (E & N A) Oct. 1888
Middlemass, Thomas, 3, Albert Place, Norton Road, Stockton-on-Tees ... ... (S) Oct. 1889
Milburn, Christopher J., 87, Morley Street, Heaton, Newcastle-on-Tyne (E) Feb. 1888
Millar, Thos., c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Walker Shipyard, Walker-on-Tyne ... ... (S) Nov. 1884
Miller, Thomas B., 6, Vernon Terrace, Gateshead-on-Tyne (E) { Graduate, Nov. 1886 / Member, Oct. 1888
Mills, John, c/o Messrs. Greenock Steam Shipping Co., Greenock (E) Feb. 1888
Mills, William, Bridge Crescent, Sunderland ... ... (E) Feb. 1890
Milne, W. J., 60, Park Road, Newcastle-on-Tyne ... ... (S) Nov. 1884
Milton, J. T., Lloyd's Register of Shipping, 2, White Lion Court, Cornhill, London, E.C. ... ... (E) Nov. 1886
Mitchell, Chas., Jesmond Towers, Newcastle-on-Tyne ... ... (S) Nov. 1884
Moffat, D., 36, Falconar Street, Newcastle-on-Tyne ... ... (E) Nov. 1884
Moffitt, George, 42, Stanley Street, Blyth ... ... (E) Oct. 1888
Moffitt, Robert, 13, Grace Terrace, Sunderland ... ... (E) Dec. 1885
Moody, Thomas V., Riding Mill, Northumberland ... ... (E) Dec. 1887
Morgan, W. H., 141, Denmark Street, Heaton, Newcastle-on-Tyne (E) Nov. 1884
Morison, D. B., 8, Albion Terrace, Hartlepool ... ... (E) Feb. 1885
Mörk, Peter, Lennox Hotel, Dumbarton, N.B. ... ... (E) Nov. 1884
Morrison, Robt., 5, Challoner Terrace, South Shields ... ... (E) Nov. 1886
Mountain, William Chas., Messrs. E. Scott & Co., Close, Newcastle-on-Tyne ... ... (E) Feb. 1889
Mudd, Thomas, Central Marine Engine Works, West Hartlepool (E) Mar. 1886
Muir, J. M., c/o Messrs. Wigham Richardson & Co., Walker-on-Tyne Nov. 1884
Muir, John, 10, Rium Terrace, Hart Road, West Hartlepool ... (E) Oct. 1888
Muir, Robert, 17, Westmorland Road, Newcastle-on-Tyne ...(SUR) Oct. 1886
Myles, David, 231, Elliot Street, Glasgow ... ... (E) Nov. 1884

N.

Nance, A. J., c/o Mr. Nance, 14, Stacey Road, Routh, Cardiff ... (E) April 1887
Napier, R. J., Lloyd's Register of Shipping, 3, St. Nicholas' Buildings, Newcastle-on-Tyne ... ...(SUR) Nov. 1888
Napier, W. E., c/o Messrs. Humphrey, Tennant, & Co., Deptford, London (E) Nov. 1884
Newitt, Leonard, c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Elswick Works, Newcastle-on-Tyne ... ... (E) Dec. 1887
Newton, Richard, Park Square, West Hartlepool ... ... (E) April 1889
Newton, W. A., 29, Sea View Terrace, South Shields (E) { Graduate, May 1885 / Member, Oct. 1886
Nichol, B. G., 49, Leazes Terrace, Newcastle-on-Tyne ... ... (E) Nov. 1884
Nichol, Thos., 50, Ripon Street, Monkwearmouth, Sunderland (SUR) Nov. 1884
Nicol, John M., 10, Linskill Place, North Shields ... ... (E) Nov. 1884
Nicolson, G. C., c/o Mr. Shearer, Victoria Jubilee School, Byker, Newcastle-on-Tyne ... ... (E) { Graduate, Oct. 1885 / Member, Oct. 1888
Nicolson, J. T., Engineering Department, University, Cambridge (E) Nov. 1884

ELECTED.

Noble, Harry, Northern Machine Tool Works, Forth Road, Newcastle-on-Tyne ... ... (E) Nov. 1888
Norman, W. S., c/o Messrs. Tyne Pontoon and Dry Docks Co., Wallsend-on-Tyne ... ... (E) Nov. 1884
Noton, F. R., 32, Azalea Terrace, Sunderland ... ... (S) Nov. 1884

O.

O'Neil, J. J. ... ... (E) Nov. 1884
Orde, E. L., Orde House, Morpeth, Northumberland ... ... (E) Oct. 1887
Oxley, G., Station Road, Howdon-on-Tyne ... ... Nov. 1884

P.

Pacey, John W., 64, Hotspur Street, Heaton, Newcastle-on-Tyne... (E) Feb. 1888
Panton, W. H., Teeside Iron and Engine Works, Middlesbrough... (E) Nov. 1887
Parsons, Hon. Charles A., Elvaston Hall, Ryton-on-Tyne ... ... (E) Dec. 1887
Parsons, P. B., St. George's Wharf, Deptford, London, S.E. ... (E) Nov. 1888
Patterson, Jas., The Green, Wallsend-on-Tyne ... ... (E) Nov. 1884
Pattison, Jos., c/o J. H. Hallett, Esq., The Docks, Cardiff... ... (E) Nov. 1884
Paulson, John, 29, Nelson Street, Greenock ... ... (S) Feb. 1886
Pease, J. F., c/o Messrs. Darlington Forge Co., Darlington... ... (E) Dec. 1888
Penny, A. W., 69, Percy Road, Whitley ... ... (S) Nov. 1884
Penney, R. H., 15, Azalea Terrace South, Sunderland ... ... (S) Nov. 1884
Pepper, W., The Groves, Yarm Road, Stockton-on-Tees ... ... (E) Nov. 1888
Petersen, John L., 18, Bellerby Terrace, West Hartlepool... ... (E) Oct. 1888
Petree, James, c/o Messrs. Laird Bros., Birkenhead ... ... (S) Oct. 1885
Phillips, John, 4, Corona Road, Burnt Ash Hill, London ... ... (E) Dec. 1889
Phillips, Walter, 108, Fenchurch Street, London, E.C. ... (N A & E) Oct. 1886
Phillipson, Roland, Tynemouth ... ... (E) Dec. 1884
Phorson, P., 86, Roker Avenue, Sunderland ... ... (S) Nov. 1884
Piaud, Leon, Bureau Veritas, 8, Place de la Bourse, Paris ... ... (N A) Nov. 1888
Pike, James J. ... ... (E) Dec. 1888
Pilcher, F. J., 3, City Buildings, Old Hall Street, Liverpool ... (S) April 1887
Pilling, J., 11, Rosslyn Terrace, Chester Road, Sunderland ... Nov. 1884
Plotnicki, E. C., 18, Frank Place, North Shields ... ... (E) Nov. 1886
Poli, Rodolfo, Chioggia, Italy ... ... (NA) Jan. 1890
Potts, Robert, 11, Mount Pleasant, Deptford, Sunderland ... ... (S) Oct. 1888
Prest, Stanley Faber, 2, Suffolk Lane, Cannon Street, London ... (E) Mar. 1888
Price, John, 6, Osborne Villas, Jesmond, Newcastle-on-Tyne ... (S) Nov. 1884
Prince, Alfred, Kent Villa, Jarrow-on-Tyne ... ... (E) Nov. 1884
Proud, Anthony, Tyne Docks, South Shields ... ... (E) Dec. 1888
Pryor, Benjamin, Experimental Tank, Royal Arsenal, Spezzia, Italy Nov. 1885
Purdy, A. J., Drawing Office, Navy Yard, Washington, D.C., U.S. of America ... ... Nov. 1884
Purves, David, 10, Holland Park Gardens, London, W. ... ... (SUR) Dec. 1885
Putnam, T., Darlington Forge, Darlington ... ... (F M) Nov. 1884
Putnam, William, Darlington Forge, Darlington ... ... (F M) Nov. 1884

ELECTED.

R.

Rae, John, 4, Grey Street, Glasgow, N.B. ... ... (E) April 1886
Ralston, G. C., 19, Fenham Road, Newcastle-on-Tyne ... ... (E) Oct. 1887
Ramage, J. T., The Hawthorns, Leith, N.B. ... ... (E) April 1887
Ramsay, C. W., Hornsborg, Lgungby, Sweden ... ... Nov. 1884
Rankine, Jno., 16, Ribblesdale Road, Hornsey, London, N. ... (E) Nov. 1884
Rayner, Thomas, 24, Side, Newcastle-on-Tyne ... ... (E) Oct. 1889
Readhead, Jas., Beach View, South Shields ... ... (S) Nov. 1884
Readhead, John, Jun., 18, Thomas Street, South Shields ... ... (E) Mar. 1886
Readhead, R., 28, Sea View Terrace, South Shields ... ... (E) Nov. 1884
Readhead, W. B., Beach View, South Shields ... ... (S) Nov. 1886
Reavell, W., 40, Guildford Road, Clapham, London, S.W. (E) {Graduate, April 1885 / Member, Oct. 1887}
Reed, Joseph, 25, Side, Newcastle-on-Tyne ... ... (E) Oct. 1889
Reed, J. W., c/o Messrs. Palmer's Shipbuilding and Iron Co., Limited, Engine Works Department, Jarrow-on-Tyne ... (E) Nov. 1884
Rennoldson, C., Messrs. J. P. Rennoldson & Sons, South Shields ... (S) Jan. 1886
Rennoldson, Jos. M., Messrs. J. P. Rennoldson & Sons, South Shields (S) Feb. 1886
Reynolds, Charles H., c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Walker-on-Tyne ... ... (S) Mar. 1889
Reynolds, Edward, c/o Messrs. Vickers, Sons, & Co., Sheffield ... (E) Jan. 1888
Reynolds, W. G., 7, St. Thomas Square, Newcastle-on-Tyne ... (E) Oct. 1886
Richardson, Wigham, Neptune Works, Walker-on-Tyne ... ... (S) Nov. 1884
Richardson, Thos., M.P., Hartlepool Engine Works, West Hartlepool (E) Oct. 1888
Richardson, Wm., Hartlepool Engine Works, West Hartlepool ... (E) Oct. 1888
Richardson, T., Jun., Hartlepool Engine Works, Hartlepool ... (E) April 1888
Rickaby, A. A., Bloomfield Engine Works, Sunderland ... ... (E)
Ridley, J. H., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne ... ... (E) Nov. 1884
Rimmington, R. F., 6, Cliff Terrace, Hartlepool ... . (E) Nov. 1888
Ritson, M., Lloyd's Register of Shipping, 2, White Lion Court, Cornhill, London, E.C. ... ... (E) Nov. 1884
Robinson, B. A., 12, Harold Street, Sunderland ... ... (E) Nov. 1884
Robinson, Frederick F., Adelphi Road, Epsom, Surrey ... ... (E) Dec. 1888
Robinson, William, 6, Choppington Street, Newcastle-on-Tyne ... ... (E) {Graduate, May 1885 / Member, April 1888}
Robson, Arthur, Messrs. J. Blumer & Co., Sunderland ... ... (S) Dec. 1886
Robson, George, 9, Wellington Terrace, South Shields ... ... (E) Oct. 1889
Robson, John H., Engineering Department, Messrs. Martinez, Rivas, & Palmer, Bilbao, Spain ... ... (E) Nov. 1885
Robson, J. M., c/o W. Whyte, B, Lombard Street, Newcastle-on-Tyne (E) Nov. 1884
Robson, M., 19, Zion Terrace, Newcastle Road, Sunderland ... (S) Nov. 1884
Roger, Robert, Stockton-on-Tees ... ... (E) Nov. 1888
Rogers, Herbert M., 10, Hartington Crescent, Stockton-on-Tees (SUR) April 1889
Ropner, Robert, Jun., Preston Hall, Stockton-on-Tees ... ... (S) Feb. 1886
Rowan, Jas., 231, Elliott Street, Glasgow ... ... (E) Nov. 1886
Rowe, John A., 13, Hampton Road, Forest Gate, London, E. ...(SUR) Oct. 1888

ELECTED.

Rowell, G. W., 1, Garden Terrace, Blaydon-on-Tyne ... ... (E) Feb. 1885
Rowell, H. ... ... Nov. 1884
Rusden, L., 11, Mistletoe Road, Jesmond, Newcastle-on-Tyne ... (E) Nov. 1884
Rutherford, G., c/o Messrs. Wallsend Slipway Co., Engine Works, Cardiff ... ... (S) Oct. 1886
Rutherford, T. A., 93, Roker Avenue, Sunderland ... ... (S) Nov. 1884
Ryder, C. L., Lloyd's Register of Shipping, Cardiff ... ... (E) Oct. 1886
Rooke, Charles Bowden, Jun., St. Paul's Road, West Hartlepool ... (E) Nov. 1889

S.

Salmon, P. R., St. Bede's Park, Sunderland ... ... (SUR) Nov. 1884
Sanderson, J., 31, Park Road, Jarrow-on-Tyne ... ... (S) Nov. 1884
Sandison, M., Elswick Shipyard, Newcastle-on-Tyne ... ... (E) Dec. 1884
Sawyers, John, c/o Messrs. Thos. Wilson, Sons, & Co., Hull ... (E) Oct. 1886
Schaeffer, A. G., 4, Benton Terrace, Newcastle-on-Tyne ... ... (E) Nov. 1884
Scorer, G. S., Messrs. T. & W. Smith, North Shields ... ... (S) Jan. 1885
Scotson, Alf., c/o Messrs. R. Stephenson & Co., Shipyard, Hebburn-on-Tyne ... ... (S) Feb. 1887
Scotson, Wm., 78, Stafford Street, Wednesbury ... . (E) Nov. 1884
Scott, Ernest, Close Engine Works, Newcastle-on-Tyne ... ... (E) Nov. 1884
Scott, George Innes, 3 Indian Kings' Court, Quayside, Newcastle-on-Tyne ... ... (E) Oct. 1889
Scott, H., 47, Mainsforth Terrace, Sunderland ... (E) { Graduate, May 1886 / Member, April 1888 }
Scott, Joseph R., 9, Queen Street, Newcastle-on-Tyne ... ... (E) Oct. 1887
Scott, Wm., 198, Portland Road, Newcastle-on-Tyne ... ... Nov. 1884
Seabury, Edward, 40, West India Road, Limehouse, London, E. ... (E) Mar. 1886
Seaman, C. J., 19, Willington Street, Stockton-on-Tees ... ... (E) Jan. 1889
Sells, C., 20, Via Almeria, Genoa, Italy ... ... (E) Oct. 1887
Shand, H., 41, Grosvenor Place, West Jesmond, Newcastle-on-Tyne (E) Nov. 1884
Sharp, A. E., 146, Albert Terrace, Jarrow-on-Tyne ... ... (E) Nov. 1884
Sharp, Mark, 144, Albert Road, Jarrow-on-Tyne ... ... (E) Dec. 1889
Sharpe, H. R., 11, Zingari Terrace, Upton Forest Gate, London ... (E) Nov. 1888
Shaw, Jas., 17, Normanby Terrace, Gateshead-on-Tyne ... ... (E) Jan. 1885
Sheriff, Thomas, Messrs. Robert Mackill & Co., Glasgow ... ... (E) April 1890
Shevill, W. H., 5, Avenue Terrace, Sunderland ... ... Nov. 1884
Short, J. Y., 49, West Sunniside, Sunderland ... ... (S) Nov. 1884
Short, Jos., 49, West Sunniside, Sunderland ... ... (S) Nov. 1884
Shotten, John W., 13, Meldon Terrace, Heaton, Newcastle-on-Tyne (SUR) Nov. 1886
Sinclair, R., c/o S. Sinclair, Esq., Australian Museum, Sydney, N.S.W. ... ... (E) Nov. 1884
Sinton, John K., 7, Grasmere Terrace, Gateshead-on-Tyne ... (E) Nov. 1885
Sisson, Wm., Gloucester ... ... (E & N A) Oct. 1888
Sisterson, G. R., Locomotive Department, London and South Western Railway, Nine Elms, London, S.W. ... ... (E) Nov. 1884
Sivewright, G. W., 5, Radcliffe Terrace, Hartlepool ... ... (S) Nov. 1886
Smith, C. Hubert, Board of Trade Offices, North Shields ... ...(SUR) May 1889

ELECTED.

Smith, C. E., 89, Scarborough Street, West Hartlepool ... ... (E) Nov. 1888
Smith, Charles Mayfield, 5, Alderson Street, West Hartlepool ... (S) April 1888
Smith, Eustace, 5, Queen Street, Newcastle-on-Tyne ... ... (S) Nov. 1884
Smith, R. J., Baltic Chambers, Sunderland ... ... (E) Nov. 1884
Smith, Reginald Thomas, 38, Belitha Villas, Barnsbury Park, London, N. ... ... (E) April 1888
Smith, Thomas, Steam Crane Works, Old Foundry, Rodley, near Leeds (E) Oct. 1888
Smith, Thomas Edward, Messrs. John Smith & Sons, Newgate Street, Newcastle-on-Tyne ... ... (E) April 1885
Smith, Wm., 51, Dock Street East, Sunderland ... ... (E) Nov. 1884
Soliani, Nabor, Connitato Pei Designa delle Navi Ministero dilla Marina, Roma, Italy ... ... (S) Jan. 1885
Soulsby, J. C., 4, Bute Crescent, Cardiff ... ... (SUR) Nov. 1886
Sowter, Isaac G., 867, East Congress Street, Detroit, Michigan, United States of America ... ... Jan. 1889
Spear, John, Messrs. T. Wilson & Sons, Hull... ... ... (E) Oct. 1887
Spearman, Richard, 118, York Street, Jarrow-on-Tyne ... ... (E) Feb. 1889
Spence, James C., Messrs. Tyne Boiler Works Co., Walker-on-Tyne, or 23, Waverey Terrace, Newcastle-on-Tyne ... ... (E) Dec. 1888
Spencer, J. W., Newburn Steel Works, Newburn-on-Tyne ... (E) Feb. 1885
Spencer, R. E. E., Palazzo Canevara, Spezzia, Italy ... ... (E) Nov. 1884
Stafford, William, Dunston-on-Tyne ... ... (E) Nov. 1885
Stephenson, C., 5, West View, Wallsend-on-Tyne ... ... (S) Nov. 1884
Stevenson, Wm., c/o Messrs. Victor Coates & Co., Princess Docks, Belfast ... ... (E) Nov. 1884
Stewart, H., c/o Messrs. Palmer's Iron and Shipbuilding Co., Jarrow-on-Tyne ... ... (E) Nov. 1888
Stirling, Andrew, Jun., 3, Greenvale Terrace, Dumbarton ... ... (E) Feb. 1888
Stirzaker, J. C., 16, Grosvenor Place, Newcastle-on-Tyne ... ... (E) Nov. 1884
Stoddart, J. E., Lloyd's Register of Shipping, Dock Office, West Hartlepool ... ... (E) Oct. 1888
Stokoe, Thomas W., 4, Lower Archer Street, West Hartlepool ... (S) Dec. 1885
Stoldtz, Heinrich, c/o Messrs. Cifuentes, Stoldtz y Co., Gijon, Spain (E) Nov. 1889
Stone, Wm. ... ... Nov. 1884
Strong, George Aaron, West Percy Street, North Shields ... ... (E) Dec. 1889
Stubbings, James, Cornhill, Sunderland ... ... (E) Nov. 1884
Summers, James, 114, Grange Road West, Middlesbrough... ... (E) Mar. 1889
Surtees, R., c/o Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne ... ... (E) Nov 1884
Sutton, James, 84, Westmorland Road, Newcastle-on-Tyne ... (S) Jan. 1885
Sutton, Jos., 84, Westmorland Road, Newcastle-on-Tyne (E) {Graduate, Mar. 1886 / Member, Oct. 1886}
Swan, A. S., Grove House, Gosforth, Newcastle-on-Tyne ... ... (S) Nov. 1888
Swan, H. F., Beaufront Castle, Hexham ... ... (S) Nov. 1884
Swan, Thomas, 152, Ellison Street, Jarrow-on-Tyne ... ... Nov. 1884
Swinburne, T. M., Bewick Road, Gateshead-on-Tyne ... ... (E) Jan. 1885

ELECTED.

Swinburne, M. W., 117, Park Road, Newcastle-on-Tyne ... ... (E) Nov. 1884
Swinney, W., 10, Wentworth Terrace, Westoe Lane, South Shields (E) Dec. 1888
Sydserff, Thomas B., Jun. ... ... (E) Oct. 1888

T.

Tate, Chas. H., 7, Side, Newcastle-on-Tyne ... ... (N A) Nov. 1884
Tatham, Stanley, 2, Cambridge Gate, Regent Park, London, N.W. (E) Feb. 1887
Taylor, Alexander, Mercantile Chambers, Quayside, Newcastle-on-Tyne ... ... (E) Nov. 1884
Taylor, C. W., South Garth, Westoe, South Shields ... ... (E) April 1885
Taylor, J. E., Lloyd's Register of Shipping, Bute Crescent, Cardiff...(SUR) Nov. 1884
Thaw, Thomas, 8, Argyle Street, Newcastle-on-Tyne ... ... (E) Dec. 1889
Thompson, C. E., Messrs. J. L. Thompson & Sons, Sunderland ... (S) Nov. 1884
Thompson, Charles, 9, Dean Street, Newcastle-on-Tyne ... ... (E) Feb. 1887
Thompson, Jas., 11, Elmwood Street, Sunderland ... ... (E) Dec. 1886
Thompson, John, Post Office Chambers, Newcastle-on-Tyne ... (E) Nov. 1884
Thompson, J. L., Jun., North Sands Shipyard, Sunderland ... (S) Nov. 1884
Thompson, Robert, North Sands Shipyard, Sunderland ... ... (S) Nov. 1884
Thompson, R. C., Bridge Dockyard, Sunderland ... ... (S) Nov. 1884
Thorn, W. H., 5, Waterville Terrace, North Shields... ... ... (E) Nov. 1884
Tinwell, George, General Gordon Terrace, Sunderland ... ... (E) Jan. 1889
Todd, Surtees, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne... ... ... (S) Nov. 1884
Todd, Thomas, 20, Billiter Street, London, E.C. ... ... (E) Nov. 1885
Tone, John M. F., 50, Clayton Park Square, Newcastle-on-Tyne ... ... (E) { Graduate, April 1885; Member, Oct. 1887 }
Towers, Edward, Jun., 4, Latimer Street, Tynemouth (E) { Graduate Nov. 1886; Member, Oct. 1888 }
Trewent, F. J., 9, Northumberland Terrace, Tynemouth ... ... (S) Dec. 1884
Tritton, S. B., Assistant Locomotive Superintendent, Eastern Bengal State Railway, Kanchrapara, Bengal, India ... (E) Nov. 1884
Tulip, George, 48, Blenheim Street, Newcastle-on-Tyne ... ... (E) Dec. 1888
Turner, Henry John, c/o Messrs. R. Stephenson & Co., South Street, Newcastle-on-Tyne ... ... (E) Feb. 1888
Turner, S. J., 74, Tynemouth Road, Heaton, Newcastle-on-Tyne... (E) Mar. 1887
Tweddell, R. H., Meopham Court, Gravesend, London ... ... (E) Jan. 1885
Tweedy, J., Neptune Works, Walker-on-Tyne ... ... (E) Nov. 1884
Twigden, George J., 80, King's Road, Canton, Cardiff ... ... (E) Jan. 1890
Tyzack, George, Dean Street, South Shields ... ... (E) April 1888

U.

Ullstrom, Otto, Messrs. Crompton, Ullstrom, & Crompton, 19, Gracechurch Street, London, E.C. ... ... (S) Nov. 1884
Ulm, John, Marine Casino, Pola, Austria ... ... (E) Nov. 1885

V.

Vianson, N. E., *vid* Galeazzo Alessi 6 into 1, Genoa, Italy ... ... (E) Dec. 1885
Vick, R. W., Messrs. E. Withy & Co., West Hartlepool ... ... (S) Nov. 1888

ELECTED.

W.

Wailes, E. F., 4, St. Nicholas' Buildings, or 13, Tankerville Terrace, Newcastle-on-Tyne ... ...(SUR) Nov. 1884
Wailes, T. W., Mount Stuart Dry Docks, Cardiff ... ... (E & S) Oct. 1887
Walker, Archibald, 147, Constitution Street, Leith, N.B. ... ... (E) April 1887
Wallau, J., c/o Messrs. Black, Hawthorn, & Co., Gateshead-on-Tyne (E) Nov. 1884
Walliker, J. F., 6, Lovaine Terrace, North Shields ... ... (E) Nov. 1885
Walton, J. G., 26, Fenchurch Street, London, E.C. ... ... (E) Nov. 1884
Warburton, J., 16, Elmwood Street, Sunderland ... ... Nov. 1884
Wardale, Henry, 5, Collingwood Terrace, Gateshead-on-Tyne ... (E) Feb. 1888
Warren, G. R., Lloyd's Register of Shipping, Constantinople ...(SUR) Nov. 1888
Watson, Ralph J., Willington House, Willington Quay-on-Tyne ... ... (E) { Graduate, Jan. 1886; Member, Oct. 1888 }
Watt, Adam, 11, Salem Hill, Sunderland ... ... Nov. 1884
Watt, Robert B., c/o Messrs. Raylton Dixon & Co., Middlesborough (S) April 1888
Watts, Philip, Elswick Shipyard, Newcastle-on-Tyne ... ... (S) Nov. 1885
Waugh, G. W., Monkseaton ... ... (E) May 1885
Weatherall, J., c/o Messrs. Naval Construction & Armament Co., Barrow-in-Furness ... ... (E) { Graduate, Oct. 1885; Member, Oct. 1887 }
Weighton, R. L., c/o Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne ... ... (E) Nov. 1884
Weir, John, Engine Department, Messrs. A. Stephens & Sons, Linthouse, Glasgow ... ... (E) Nov. 1884
Weir, William, c/o Messrs. Wigham Richardson & Co., Walker-on-Tyne ... ... (E) Nov. 1889
West, Henry H., 14, Castle Street, Liverpool ... ... (E & N A) Oct. 1886
Westgarth, Tom, Messrs. Westgarth, English, & Co., Middlesborough (E) Oct. 1886
Westmacott, P. G. B., Elswick Engine Works, Newcastle-on-Tyne (E) Nov. 1884
White, C., 13, Mosley Street, Newcastle-on-Tyne ... ... (E) Nov. 1884
White, R. S., Fairfield Works, Govan, Glasgow ... ... (S) Nov. 1884
Whyte, Wm., B, Lombard Street, Newcastle-on-Tyne ... ... (E) Nov. 1884
Widdas, T. D., 5, St. Nicholas' Road, Aigburth Road, Liverpool (SUR) April 1885
Wiles, John W., 18, Salisbury Street, South Shields ... ... (S) Nov. 1886
Wilkie, J., 9, Croft Avenue, Sunderland ... ... (E) Nov. 1884
Willcox, F. W., 45, Sunniside West, Sunderland ... ... (E) Nov. 1884
Williams, J., 3, Azalea Terrace, Sunderland ... ... (SUR) Nov. 1884
Williams, T. Fitzroy, 64, Linskill Terrace, Tynemouth ... ... (E) Feb. 1890
Wilson, J. T., Spennymoor House, Spennymoor ... (E) { Graduate, April 1885; Member, Feb. 1886 }
Wilson, Robert ... ... (S) Oct. 1887
Wilson, William ... ... (S) Oct. 1885
Winstanley, P. D., c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Elswick, Newcastle-on-Tyne ... ... (E) Nov. 1884
Withy, H., Middleton Shipyard, West Hartlepool ... ... (S) Nov. 1884
Worsdell, Wilson, North-Eastern Locomotive Works, Gateshead-on-Tyne ... ... (E) Dec. 1888
Wotherspoon R., Board of Trade Offices, West Hartlepool... ... (E) April 1889
Wright, R., 25, Westmorland Road, Newcastle-on-Tyne ... ... Nov. 1884

ELECTED.

Y.

Young, J. D., 16, Western Hill, Sunderland ... ... (E) Oct. 1888
Younger, R., Elmire House, Heaton, Newcastle-on-Tyne ... ... (E) Nov. 1884

Z.

Zeltz, A. ... ... (E) Nov. 1884
Zeeman, J. H., c/o Messrs. The Maas Co., Rotterdam ... ... (S) Oct. 1889

ASSOCIATES.

A.

Allden, William R., Akenside Villa, Newcastle-on-Tyne ... ... (A) Dec. 1886
Armstrong, S., 14, Victoria Place, Hartlepool ... ... (A) Nov. 1888

B.

Barklam, George, Tipton, Staffordshire ... ... April 1888
Barwick, J. S., Ashbrook Grange, Sunderland ... ... (S O) Nov. 1884
Bell, John Henry, North Cliff, Roker, Sunderland ... (I & S M) Oct. 1887
Bigge, C. W., Northern Counties Club, Newcastle ... ... (A) Dec. 1889
Boyd, Robert, Messrs. Hannay, Boyd, & Co., Quay, Newcastle-on-Tyne ... ... (S O) Nov. 1884
Branfoot, W. J., Messrs. Tyzack & Branfoot, John Street, Sunderland ... ... (S O) Dec. 1887
Briggs, R. S., Moorlands, Sunderland ... ... (S O) Dec. 1886
Brunton, John, 3, Prior's Terrace, Tynemouth ... ... (S O) Oct. 1886
Byers, Wm. Lumsdon, 51, West Sunniside, Sunderland ... ... (S O) Oct. 1888

C.

Carr, Ralph, Thornleight, Clayton Park Road, Newcastle-on-Tyne (A & S O) Nov. 1886
Cassap, William, 23, Cawley Road, Victoria Park, London, N.E. ...(SUR) Feb. 1890
Charlton, W. A., St. Nicholas' Buildings, Newcastle-on-Tyne ... (A) Mar. 1888
Cohan, Edward Asher, 2, Rumford Place, Liverpool ... ... (S O) Nov. 1889
Common, Francis James, 5, Elms West, Sunderland ... (I & S M) Oct. 1887
Corbitt, Michael, Rope Works, The Teams, Gateshead-on-Tyne ... (R M) Jan. 1890
Coull, John, 43, Stanley Street West, North Shields ... ... (S O) Oct. 1886
Coverdale, R. H., Messrs. J. Coverdale & Sons, Steamship Owners, West Hartlepool ... ... (S O) Nov. 1888
Crosier, Edward James, 9, Lincoln Terrace, Gateshead ... ... (A) Oct. 1889
Crowther, Joseph, Dispensary Lane, Newcastle-on-Tyne ... ... (I M) Jan. 1889
Culliford, J. H. W., 45, West Sunniside, Sunderland ... ... (S O) Nov. 1884

D.

Dixon, Robert, Rope Works, The Teams, Gateshead-on-Tyne ... (R M) Jan. 1890
Dodds, A. P., 13, Dean Street, Newcastle-on-Tyne ... ... (A) Jan. 1889
Dodds, Charles Henry, General Manager River Wear Commission, 16, Thornhill Terrace, Sunderland ... ... Oct. 1887
Dodds, John B., 13, Dean Street, Newcastle-on-Tyne ... ... Oct. 1888

ELECTED.

F.

Furness, Christopher, Victoria Terrace, West Hartlepool ... ...(S O) Oct. 1888

G.

Garnett, William, Principal, The Durham College of Science, Newcastle-on-Tyne ... ... Jan. 1889
Gjemre, Lauritz, Maritime Buildings, King Street, Newcastle-on-Tyne ... ...(S O) Mar. 1886
Greenwell, Thos. G., Sunderland ... ...(S O) Dec. 1886

H.

Harland, George, 1, Westoe Crescent, South Shields ... ... (A) Dec. 1888
Hedley, John H., 10, Esplanade West, Sunderland ... ... (S) Dec. 1886
Heslop, Richard O., Akenside Hill, Newcastle-on-Tyne ... (I & S M) Oct. 1885
Hogg, George J. H., N.E.C. Insurance Association, West Hartlepool (S O) Oct. 1888
Hollis, H. E., 3, St. George's Terrace, Jesmond, Newcastle-on-Tyne (I & S M) Feb. 1885
Hudson, Ralph M., Jun., 8, The Cedars, Sunderland ... ... (S O) Dec. 1886
Hunting, Charles, Jesmond Dene, Newcastle-on-Tyne ... ...(S O) April 1886

I.

Iley, D. W., 1, Elmwood Street, Sunderland ... ... (I & S M) Nov. 1888

J.

Jenkins, William, Consett Hall, Durhamshire ... ... (I & S M) Nov. 1887
Jobson, W. J., c/o Messrs Robert Stephenson & Co., South Street, Newcastle-on-Tyne ... ... (A) May 1889

K.

Kerr, James, 18, Azalea Terrace South, Sunderland ... ... (A) Jan. 1888

L.

Loveridge, W. H., Mainsforth Terrace, West Hartlepool ... (I & S M) Oct. 1888

M.

Macarthy, George E., 9, Dean Street, Newcastle-on-Tyne ... ...(S O) Oct. 1887
Matthiessen, P. H., 12, Lombard Street, Newcastle-on-Tyne ... (A) Oct. 1888
Maughan, William, Westmorland Road, Newcastle-on-Tyne ... (A) Feb. 1887
Mawson, Rowland, Bank Chambers, Quay, Newcastle-on-Tyne ... (S O) Jan. 1889
McNabb, Thos., Cail's Buildings, Quayside, Newcastle-on-Tyne ...(S O) Nov. 1886
Metcalf, Thomas, Sea View Gardens, Roker, Sunderland ... (SUR) Jan. 1888
Milburn, J. D., Queen Street, Newcastle-on-Tyne ... ...(S O) Nov. 1884
Miller, T. R., c/o Messrs. Lamplough & Co., 72, Cornhill, London ... ... (A & S O) Nov. 1884
Mudd, John, Sunderland ... ... (I & S M) Nov. 1884
Mulherion, G. F., 144, Albert Road, Jarrow-on-Tyne ... ... (A) Nov. 1884
Muller J. C. F., 28, Vieille Route, Antwerp ... ...(SUR) Feb. 1890

ELECTED.

N.

Newby, S., Messrs. Thomson & Newby, 13, Bridge Street Sunderland ... ... (I & S M) Nov. 1884

O.

O'Hagan, James, St. Nazaire-sur-Loire, France ... ... Oct. 1888
Osbourne, Jas., Hylton, Sunderland ... ... (S) Jan. 1885

P.

Panton, Hugh, 38, Fawcett Street, Sunderland ... ... (I & S M) Nov. 1887
Patterson, John, 28, Belgrave Terrace, Newcastle-on-Tyne ... (A) Feb. 1885
Patterson, Thos., 6, Argyle Square, Sunderland ... ... (S) Jan. 1885
Pattison, W. J., Messrs. Hunting & Pattison, Exchange Buildings, Quayside, Newcastle-on-Tyne ... ...(S O) April 1886
Perry, Edwin, 23, Side, Newcastle-on-Tyne ... ... (A) Nov. 1885
Phalp, Oliver, Almora, 37, Richmond Road, Cardiff ... ...(SUR) Feb. 1889
Pinkney, Thomas, Creswell Villa, Sunderland ... ...(S O) Dec. 1886
Pinkney, T. W., John Street, Sunderland ... ...(S O) Feb. 1888
Pirrie, Robert Reid, Guildhall Chambers, Quay, Newcastle-on-Tyne (S O) Dec. 1889

R.

Ramsay, J. W., 13, Northbrook Road, Lee, Kent ... ... (A) Feb. 1885
Reichwald, A., Lombard Street, Newcastle-on-Tyne ... ... (A) Nov. 1884
Reid, Andrew, Printer, Akenside Hill, Newcastle-on-Tyne ... Nov. 1884
Renwick, G., Messrs. Fisher, Renwick, & Co., Queen Street, Newcastle-on-Tyne ... ...(S O) Nov. 1884
Robson, Frederick, 46, Dean Street, Newcastle-on-Tyne ... ... Oct. 1887
Robson, Thos., 28, North Bridge Street, Sunderland ... ...(S O) Nov. 1884

S.

Sanderson, John, 9, The Elms, Sunderland ... ...(S O) Dec. 1886
Scholefield, A., 17, Sandhill, Newcastle-on-Tyne ... ...(S O) Nov. 1884
Scott, W. H., Messrs. Scott Brothers, Dean St., Newcastle-on-Tyne (S O) Nov. 1884
Smith, George, c/o Messrs. Hawthorn, Leslie, & Co., St. Peter's Works, Newcastle-on-Tyne ... ... (A) Feb. 1889
Snowdon, W. F., Salter's Road, Gosforth, Newcastle-on-Tyne ... (E A) Dec. 1886
Squance, J. W., Marine Superintendent, 13, The Avenue, Sunderland April 1888
Stephens, D., Messrs. Stephens, Mawson, & Co., Bank Chambers, Quay, Newcastle-on-Tyne ... ...(S O) Nov. 1884
Swan, Isaac J., Grove House, Gosforth, Newcastle-on-Tyne ...(S O) Feb. 1888

T.

Taylor, John W., Thornhill Tower, Sunderland ... ...(S O) Dec. 1886
Temperley, C., 9, Gracechurch Street, London ... ...(S O) Nov. 1885
Thompson, V. T., Baltic Chambers, Sunderland ... ...(S O) Dec. 1886
Towers, Edward, 4, Latimer Street, Tynemouth ... ... (A) Oct. 1888
Tweedy, George, Gresham House, Bishopsgate Street, London ... (S O) Mar. 1889

ELECTED.

V.

Varley, John, 257, High Park Road, Leeds ... ... (I & S M) Mar. 1887

W.

Wait, James, Maritime Buildings, King Street, Newcastle-on-Tyne (S O) Nov. 1884
Wallace, Wm., 27, South Scarborough Street, West Hartlepool ... (A) Oct. 1888
Ward, Joseph, c/o Messrs. Wallsend Slipway Co., Wallsend-on-Tyne (A) Nov. 1886
Warren, Reuben Hynard, 151, Park Road, Newcastle-on-Tyne ... Mar. 1890
Welford, Richard, Gosforth, Newcastle-on-Tyne ... ... (S O) April 1888
Woods, James Jabez, Messrs. Herskind & Woods, West Hartlepool (S O) Oct. 1888

Y.

Yeoman, F., Messrs. Murrell & Yeoman, West Hartlepool ... (S O) Nov. 1888
Young, William M., Guildhall Chambers, Newcastle-on-Tyne ... (S O) Mar. 1889
Younger, Robert Laurie, Messrs. Greenock Steamship Co., Limited, Greenock ... ... (A) Feb. 1889

GRADUATES.

A.

Adamson, Daniel, c/o Messrs. Joseph Adamson & Co., Hyde ... ... Feb. 1888

B.

Blackett, Walter, 6, Windsor Crescent, Newcastle-on-Tyne ... ... Nov. 1886
Blakey, John Henry, 5, Cambridge Street, Newcastle-on-Tyne ... ... Dec. 1889
Boyd, William, Jun., North House, Long Benton, Newcastle-on-Tyne ... Nov. 1887
Brodin, Olof, 6, Park Terrace, South Shields ... ... Mar. 1890
Bryson, John J., 69, Mount Pleasant, Barrow-in-Furness ... ... Feb. 1889

C.

Coull, Alex. B., 43, Stanley Street W., North Shields ... ... Feb. 1887
Crosby, J., 1, Randolph Street, Sunderland ... ... May 1885

D.

Dixon, John R., 79, Osborne Road, Jesmond, Newcastle-on-Tyne ... Oct. 1887
Donkin, Samuel, 5, Dean Terrace, Southwick, Sunderland ... ... Jan. 1888
Duckitt, J. Brentnall, 9, St. James' Street, Newcastle-on-Tyne ... ... Oct. 1888

F.

Fairbairn, Jas., Hendon Valley Road, Sunderland ... ... May 1885
Finch, Herbert K., 10, Eversley Place, Heaton, Newcastle-on-Tyne ... Dec. 1888
Foley, Wm. C. le B. .. .. Nov. 1887

G.

Gaine, Roger L., 17, Park Place E., Sunderland ... ... Dec. 1887
Gibson, W. H., East Farm, Fourstones ... ... Jan. 1890
Gilmour, William Laidlaw, Messrs. R. Stephenson & Co., Ld., Hebburn-on-Tyne ... ... Mar. 1890

ELECTED.

H.

Hamilton, James, 3, Victoria Square, Newcastle-on-Tyne ... ... Oct. 1887
Henshall, Samuel, 9, Chester Road, Sunderland ... ... May 1885
Hilbert De Mattos, James ... ...
Holey, J. T., 17, Rainton Street, Millfield, Sunderland ... ... Jan. 1886
Hume, Alfred Ernest, 34, Burdon Terrace, Newcastle-on-Tyne ... ... Oct. 1888

I.

Ingram, Herbert P., 30, Brougham Street, East Hartlepool ... ... April 1888

K.

Keen, Harry Bernard, 6, Beauclere Terrace, Sunderland ... ... Dec. 1889

L.

Lander, John, Messrs. Wigham Richardson & Co., Walker-on-Tyne ... Dec. 1889
Lewis, Ernest Edward, 68, Crown Street, Newcastle-on-Tyne ... ... Mar. 1890
Liebert, Richard A. E., 214, Portland Road, Newcastle-on-Tyne ... ... Dec. 1888

M.

McRobie, Frank, 14, Westmorland Terrace, Newcastle-on-Tyne ... ... Mar. 1889
Metcalf, Thos., Sea View Gardens, Roker, Sunderland ... ... May 1885
Moffatt, James, 2, Clan Brassil Terrace, Marino, Co. Down, Ireland ... Dec. 1889

N.

Nicholson, C., 9, Sussex Place, Southampton ... ... Nov. 1888
Nicholson, Philip Foster, Sandfield, West Boldon, near Sunderland ... Dec. 1889

O.

Orr, Reginald, 185, Albert Road, Jarrow-on-Tyne ... ... Mar. 1890

R.

Reed, Joseph, Springfield, Forest Hall ... ...
Rickaby, Augustine, Bloomfield Engine Works, Monkwearmouth, Sunderland ... ... Nov. 1885
Ritson, Stanley M., 18, St. Bede's Terrace, Sunderland ... ... Nov. 1887
Roberts, T. C., c/o Messrs. Wigham Richardson & Co., Neptune Shipyard, Walker-on-Tyne ... ... Oct. 1886
Ross, Wm. Chisholm ... ... Dec. 1888
Rutherford, J. T., 80, Rychill, Newcastle-on-Tyne ... ... Jan. 1886

S.

Shaw, Thomas, West Boldon, near Sunderland ... ... Dec. 1885
Skinner, Leslie, 22, Ravensbourne Terrace, South Shields ... ... Dec. 1886

ELECTED.

Smith, Launcelot Eustace, 62, Rye Hill, Newcastle-on-Tyne ... ... Oct. 1889
Stoddart, Swinton, 24, North Milburn Street, Sunderland ... ... May 1885
Strang, T. Rankine, 53, Beverley Terrace, Cullercoats ... ... Nov. 1888

T.

Taylor, M., Hawthorn Road, Gosforth, Newcastle-on-Tyne ... ... Feb. 1889

W.

Westmacott, Alfred, Benwell Hill, Newcastle-on-Tyne ... ... Dec. 1885
Wheeler, O., c/o Messrs. Wigham Richardson & Co., Neptune Works, Walker-on-Tyne ... ... Oct. 1886
White, Ernest T., 3, Belle Vue Terrace, Gateshead-on-Tyne ... ... May 1889
Wilkinson, Thomas, 14, West View Terrace, Lemington ... ... Mar. 1890
Wortley, H., c/o Messrs. R. Stephenson & Co., Shipyard, Hebburn-on-Tyne ... ... Jan. 1886

MEMOIRS.

THE LATE MR. WILLIAM CLARKE.

Mr. William Clarke was born in Sunderland in the year 1831, and spent his youthful days at Bedlington, his father at that time holding an important position in the Bedlington Engine Works. At the age of 14 he entered these works as an apprentice under the management of Mr. Longridge. In the year 1852 he quitted Bedlington, and after spending some time in the works of Messrs. Sir W. G. Armstrong & Co., at Elswick, he joined the Walker Ironworks as assistant to Mr. George Dove, where he remained for five years. He then joined the firm of Messrs. Abbot & Co., Gateshead-on-Tyne, as manager of their engineering department, which position he held for about five years. In the year 1864, he, in conjunction with Messrs. Watson & Gurney, began business in a small engineering works at the South Shore, Gateshead; but their business increased so rapidly as to necessitate their removal to more extensive premises. Accordingly new works were built in Gateshead, under the supervision of Mr. Clarke, and named the Victoria Engine Works. These works which were entered in the year 1874, are replete with every modern appliance for the carrying on of the special trade for which the firm has gained a notoriety, and bear testimony to the enterprise, skill, and energy of the deceased member of the firm. Mr. Clarke also held the important position of consulting engineer for the building and erecting of the chain cable and anchor testing machinery in Lloyd's Test Houses at Walker-on-Tyne, Sunderland, Glasgow, and Bristol. He died on the 31st of July, 1890.

THE LATE MR. ALEXANDER HEPBURN.

Mr. Alexander Hepburn was born at Sunnyside, in the Parish of Banchory, Devenick, Aberdeenshire, in the year 1848, and was educated at Cults School and Rennet's Mathematical Academy, Aberdeen. At the age of 15 he entered his father's millwright works, at Cults, as an apprentice, and after serving five years, he went to Birkenhead, and continued for some time in the employ of Messrs. Laird Bros. Subsequently he went to sea as an engineer. On leaving the sea he joined his brother, Mr. George Hepburn, consulting engineer and naval architect, of Liverpool, who took him into partner-

ship, and sent him to Newcastle-on-Tyne to open an office and manage their business on the North-East Coast. After some years the partnership was dissolved, Mr. Alex. Hepburn continuing the business in Newcastle. His services as consulting and superintendent engineer were retained by Messrs. Adam & Co., of Aberdeen, Newcastle, and London, the Aberdeen, Newcastle, and Hull Steam Shipping Company, and others. Previous to his decease he had been for a considerable time in indifferent health, but had so much improved as to be able to attend to his regular duties, in the discharge of which he was struck down and died somewhat suddenly on the 7th December, 1889. Naturally he was of a retiring disposition and void of all assumption, but his geniality gathered round him many friends.

THE LATE THOMAS WILSON.

Mr. Thomas Wilson was born at Inverneil, Ardrishaig, Argyleshire, in the year 1843. He began his early training as an engineer with Messrs. Denny & Co., Dumbarton. Having completed his engagement with them he entered the employ of Messrs. John Elder & Co., of Fairfield, and subsequently that of Messrs. J. & S. Thompson, of Dalmuir. He then went to sea and qualified as a first class engineer, after which he joined the firm of Messrs. Jardine, Mathieson & Co., China, in whose employ he remained for several years. Returning to England he spent some time in the works of Messrs. Amos & Smith, of Hull, and became connected with the Wilson Line of Steamers; and subsequently he was appointed engineer surveyor to Lloyd's Register of Shipping on the River Tyne. While in this capacity he was offered and accepted the appointment of manager over the engineering department of the Wallsend Slipway Co., which he held for about six years. Finally, he accepted the appointment of superintendent engineer to the General Steam Navigation Co., and manager of their works at Deptford on the Thames, where he remained until his death, which took place after a very short illness, on the 15th January, 1890. Being of an affable and genial temperament he made many friends during his sojourn on the North-East Coast, and the news of his sudden and unexpected decease was received with feelings of deep regret by all who knew him.

THE NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

Constitution and Bye-Laws,

ADOPTED AT A GENERAL MEETING ON THE 4TH MARCH, 1885.

REVISED AT THE CLOSING BUSINESS MEETING HELD ON MAY 4TH, 1887.

RE-REVISED AT THE CLOSING BUSINESS MEETINGS HELD ON MAY 9TH, 1888, AND MAY 13TH, 1889.

CONSTITUTION.

I.—The NAME of the Association is "The North-East Coast Institution of Engineers and Shipbuilders." Name.

II.—The OBJECTS for which the Institution is established are:—The advancement of the science and practice of Engineering and Shipbuilding, and the interchange of ideas and information amongst its members, by means of meetings for the reading and discussion of papers relating thereto, and placing on record its transactions. Objects.

III.—The Institution shall consist of Honorary Members, Members, Associates, and Graduates.

IV.—HONORARY MEMBERS shall be such distinguished persons as the Council may elect. Honorary Members.

V.—MEMBERS shall be Principals or Principal Managers engaged in Engineering or Shipbuilding; Civil, Military, or Mining Engineers, or Naval Architects; whose subscription shall be Two Guineas per annum: and other persons engaged in the above professions; whose subscription shall be One Guinea per annum. Members.

VI.—ASSOCIATES shall be such persons as are not strictly Engineers or Shipbuilders, but are connected with or interested in such pursuits, and are deemed by the Council to be eligible for Associate membership. Their subscription shall be One Guinea per annum. Associates.

Graduates.

VII.—GRADUATES may be persons under twenty-four years of age, engaged in study or employment to qualify themselves for any of the above professions. Their subscription shall be Half-a-Guinea per annum.

Life Members and Associates.

VIII.—Any MEMBER may become a LIFE MEMBER by a single payment of Twenty Guineas, or any ASSOCIATE may become a LIFE ASSOCIATE by a single payment of Ten Guineas.

Officers.

IX.—The OFFICERS of the Institution shall be elected from and by the Members, and shall consist of one President, the Past-Presidents, nine Vice-Presidents, fifteen Councilmen, and an Honorary Treasurer.

Election of Officers. (See Bye-Law No. 11.)

X.—The President and Honorary Treasurer shall be elected annually. Three Vice-Presidents and five Councilmen shall be elected annually. The retiring Vice-Presidents and Councilmen shall be those who have served three years from their last election.

The President shall be eligible for re-election for a second year; should he be re-elected he shall retire at the conclusion of his second year of office, and shall not again be eligible until after an interval of one year.

The retiring Vice-Presidents and Councilmen shall not be eligible for re-election to the same offices until after a similar interval, but shall be eligible for election to any other office.

The Honorary Treasurer shall be eligible for re-election annually, or for election to any other office.

Honorary Members' Privileges.

XI.—Honorary Members may attend all the General Meetings, they may read papers, take part in discussions, in voting, in moving and supporting resolutions, in presentation of notices of motion, or in requisitions for Special Meetings, and in the proposition of new members; they shall also receive copies of the Transactions.

Members' Privileges.

XII.—Members shall have all the privileges of the Institution as enumerated in the foregoing paragraph, and shall be eligible for office.

Associates' Privileges.

XIII.—Associates shall have all the privileges enumerated in paragraph XI. They shall be eligible for office as Councilmen.

XIV.—Graduates may attend all the General Meetings, they may read papers, take part in discussions, and support resolutions; they shall also receive copies of the Transactions, but shall not sign proposals for new members, vote, nor be eligible for office. Graduates' Privileges.

XV.—The General Meetings of the Institution shall be held during the winter seasons of each year. General Meetings.

NOTE.—When the word Member is initialled with a capital letter it signifies a member under paragraphs IV. and V., but when initialled with a small letter, it signifies a member of any class of the Institution membership.

BYE-LAWS.

Revised at the Closing Business Meetings held on May 4th, 1887, *and May 13th*, 1889.

MEMBERSHIP.

1.—Every candidate for admission as a Member, Associate, or Graduate shall be proposed and recommended according to the form A in the Appendix, in which form the name, usual residence or the place of business, the qualification for, and proposed class of membership of the candidate shall be distinctly specified. Proposals for Graduates must give the date of, and age, last birthday. Candidates for Admission.

The form shall be signed by a Member or Associate of the Institution, as proposer, and by at least other three Members or Associates as supporters, certifying a personal knowledge of the candidate.

The proposal so made shall be submitted to the Council, when, if it be approved, the Chairman shall sign the approbation, which shall be inserted in the notice calling the next General Meeting, when the candidate shall be balloted for, and shall be accepted if three-fourths of the votes are favourable.

2.—Graduates desirous of becoming Members shall be proposed and recommended according to the Form B in the Appendix. Graduates becoming Members

The proposal so made shall be submitted to the Council, who shall agree to or reject it.

3.—The balloting for membership shall be conducted in the following manner:—Each member shall be supplied by post with Balloting for Members.

a list of the names of the candidates, according to the Form C in the Appendix, and shall strike out the names of such candidates as he desires shall not be elected. These lists may be returned to the Secretary by post, or may be deposited in the ballot-box by the voter in person on entering a meeting at which an election is to take place. The ballot-box will be closed at ten minutes after the advertised time of meeting. The lists shall then be handed over to the Chairman, who shall appoint two Scrutineers to examine them, after which examination the Chairman shall inform the meeting of the result.

Candidates to receive Notice of Election.

4.—Notice of Election as a member shall be sent to the candidate within one week after his election, according to the Form D in the Appendix; but his name shall not be added to the list of Members, Associates, or Graduates of the Institution, until he shall have paid his first annual subscription.

Rejection of Candidates.

5.—In case of rejection of the candidate, no mention thereof shall be made in the minutes, nor shall any notice be given to the unsuccessful candidate.

Subscriptions payable in Advance.

6.—All subscriptions shall be payable in advance, and shall become due on the 1st of June each year. Any Member, Associate, or Graduate, wishing to retire from the Institution shall continue to be liable for his annual subscription until he shall have given formal notice of his retirement to the Secretary, which notice must be given on or before the 31st of August in each year. Application for membership may be made at any time during a Session, and the subscription shall cover the membership up to the 1st of June following.

Receipt of Subscription.

7.—On payment of each subscription the Secretary shall forward to the member an official receipt.

Questions of Privilege.

8.—On question of privilege.—Any person who may be unknown in the meeting shall only be able to claim the privilege in question on proving his membership for the current Session.

Arrears of Subscriptions.

9.—Any member whose subscription is one year in arrear shall be reported to the Council, who shall direct application to be made for it, according to Form E in the Appendix; and in the event of its continuing in arrear until the end of that

Session after such application, the Council shall have the power, after remonstrance by letter, according to the Form F in the Appendix, of declaring that the defaulter has ceased to be a member.

Power of Council to remove Name from List of members.

10.—The Council may refuse to continue to receive the subscriptions of any member who shall have wittingly acted in contravention of the Regulations of the Institution, or who shall, in the opinion of the Council, have been guilty of such conduct as shall have rendered him unfit to continue his membership; and the Council may remove his name from the list of members: and such person shall thereupon cease to be a member of the Institution. Notice of such action of the Council shall be forwarded to the person in question, in accordance with the Form G in the Appendix. The reason for such action of the Council shall not be stated to the person expelled, without the sanction of the Council.

OFFICERS.

Election of Officers.

11.—The Annual Election of Officers shall be conducted in the following manner:—The Council shall meet in March or April, and shall arrange a list of nominations, in accordance with the Form H in the Appendix. Such list shall be presented at the General Meeting immediately preceding the last General Meeting of the Session, and any Member present shall be at liberty to nominate additional Members. The list shall show who remain in office throughout the Council, and who are retiring. It shall nominate new names in the place of the retiring Members, and the number of nominations shall be, at least, two in excess of the number required in each section of the Council. A copy of this ballot list shall be forwarded to each Member and Associate, together with a complete list of Members, to be filled in, in accordance with the instructions printed in the ballot form, and to be returned to the Secretary, to be opened in the presence of the Council, at a Council Meeting which shall be held in April or May, when the scrutiny and counting shall be carried out by the Council. Any Member in voting shall be at liberty to erase any name or names from the

list and substitute the names of any other person or persons eligible for each respective office other than those already placed on the ballot list by the Council and Members of the Institution.

Any voting paper returning either more or less than one President, six Vice-Presidents, one Honorary Treasurer, and fifteen Councilmen, shall be disqualified for the section or sections in which such errors occur, and the votes shall be lost for the said section or sections. The votes given as President, to a Member who is not elected President, shall count to him as a Vice-President; the votes given as Vice-President, or Treasurer, to persons not so elected, shall count to them as Councilmen, unless they have just completed a term of office in such capacity.

The voting list shall not be sent to any Member and Associate whose subscriptions are more than one year in arrear; nor shall any Member be nominated on the list. For this purpose, the Secretary shall prepare, previously to the meeting of Council, a list of those Members whose subscriptions are more than one year in arrears.

Ballot to be declared at May Meeting

12.—The result of the ballot for Officers shall be declared at the General Meeting, to be held in May, at which meeting general business shall be transacted. At the May General Meeting the newly-elected Officers, after being declared, shall enter into office; and this shall be the last meeting of the Session.

Power of Council to fill up Casual Vacancy.

13.—The Council shall have power to supply any casual vacancy within itself (including any casual vacancy in the office of President), which shall occur between one May Meeting and another; and the Officers so appointed shall retire when the person whose place they fill would have retired. Vacancies not filled up during the year shall be filled at the General Election.

GENERAL MEETINGS.

General Meetings.

14.—The Annual General Meeting shall take place in October, and shall be held in Newcastle. The Ordinary Meetings shall take place in the second week in each following month during the Session, unless otherwise arranged by the Council, and at such hours and places as the Council may determine.

15.—Seven clear days' notice of every General Meeting, Ordinary or Special, specifying the nature of business to be transacted, shall be given to every member of the Institution. Notice of Meetings.

16.—A Special General Meeting may be convened at any time by the Council, and such meeting shall be convened by the Council whenever such is the declared wish of a General Meeting, or whenever a written requisition, signed by twenty members, specifying the object of the meeting, is left with the Secretary. If, for fourteen days after the delivery of such requisition, a meeting be not convened in accordance therewith, the requisitionists, or any twenty members of the Institution, may convene a Special Meeting in accordance with the requisition. The business discussed at such Special Meetings shall only be that indicated on the notice calling the meeting. Special General Meetings.

17.—Twenty Members shall constitute a quorum for the purpose of a meeting other than a Special Meeting. Thirty Members shall constitute a quorum for the purpose of a Special meeting. Quorum.

18.—The President shall be chairman at every meeting, and in his absence, one of the Past-Presidents or one of the Vice-Presidents; or in the absence of these, a Councilman shall take the chair; or if no Councilman be present and willing to take the chair, the meeting shall elect a Chairman. Chairman at Meetings.

19.—The decision of a General Meeting shall be ascertained by a show of hands; or, when five Members or Associates shall demand, or the Chairman may think it desirable, the decision shall be taken by ballot. The manner of counting the votes shall be at the discretion of the Chairman, and an entry in the minutes, signed by the Chairman, shall be deemed sufficient evidence of the decision of a General Meeting. In cases of equality of votes, the Chairman shall have a casting vote; otherwise he shall not vote. Decisions of General Meetings.

20.—Questions of a personal nature arising in a General Meeting, shall, if possible, be referred to the Council, otherwise the decision of the meeting shall be taken by ballot on a motion or amendment put to the meeting. The ballot shall be taken by the voters (being Members or Associates) writing "for" and "against" on a slip of paper. The slips shall be folded and Questions of a Personal Nature in General Meetings.

collected, and then counted in the presence of the meeting, and the result announced by the Chairman. Should fewer than twenty votes be given, it shall be understood that the question is shelved, and the votes shall be destroyed without being opened.

Transactions of Business General Meetings.

21.—At every General Meeting of the Institution, the Secretary shall first read the minutes of the preceding meeting, which, on approval, shall be signed by the Chairman; business arising out of these minutes shall then be transacted. The Secretary shall read any notices which may have to be brought before the meeting. Notices of motion may then be given, and other business of the Institution may be attended to; but when a paper is to be read, the foregoing business shall not be extended beyond half-an-hour after the advertised time for commencing the meeting. The paper or papers for the evening shall then be read and discussed.

Dissolving a General Meeting.

22.—If within half-an-hour after the time fixed for holding a General Meeting a quorum is not present, the meeting shall be dissolved, and all matters which might, if a quorum had been present, have been done at the meeting so dissolved, may forthwith be done on behalf of the meeting, by the Council; except the reading or discussion of a paper, which shall not proceed in the absence of a quorum.

Adjourning a General Meeting.

23.—Any General Meeting of the Institution may be adjourned by a vote of the Members and Associates present if there be a quorum; if there be not a quorum, the case shall be met by the preceding paragraph.

Introduction of Friends.

24.—Each member shall have the privilege of introducing one friend to the General Meetings, whose name must be written in the Visitors' Book, together with that of the member introducing him; but if the introducing member be unable to attend the meeting, he may send the name of the visitor to the Secretary. During such portions of any of these meetings as may be devoted to any business connected with the management of the Institution, visitors may be requested by the Chairman to withdraw. This shall be done if five Members or Associates, or both, present request it.

COUNCIL MEETINGS.

25.—The Council shall meet before each General Meeting, or on other occasions when the President shall deem it necessary; being summoned in either case by circular, stating the time of meeting, and the business, so far as is known. Council Meetings.

No business involving expenditure of the funds of the Institution (except by way of payment of current accounts) shall be transacted at any Council Meeting, unless the circular gives six clear days' notice, and states the business. Convening Meeting for Expenditure of Funds.

All discussions of a personal character in the Council shall be considered and treated as being strictly confidential. Discussions of Personal Character.

26.—The Council may regulate its own procedure, and delegate any of its powers and discretions to any one or more of its number. Regulation of Proceedings.

The President shall, *ex-officio*, be chairman of all Council Meetings, and in his absence one of the Past-Presidents or one of the Vice-Presidents shall take the chair; or in the absence of these, one of the Councilmen shall be elected to take the chair. Five members of Council, including the Chairman, shall form a quorum. Chairman and Quorum.

In the appointment of Sub-Committees, the Council shall determine the number which shall form a quorum in each case, and shall appoint a Chairman. These regulations shall not affect the Finance Committee. Sub-Committees.

27.—The Council may appoint Committees either from itself, or with the assistance of persons outside, for the purpose of transacting any special business, or of investigating specific objects connected with the work and interests of the Institution. Sub-Committees.

28.—All Committees or Sub-Committees shall be appointed by the Council, and shall be subject to that body, and shall report to it. The Council shall act upon these reports or recommendations as it may think best. Sub-Committees.

29.—The Council may invite to General Meetings or to Council Meetings any person or persons whose presence and assistance it may desire, and strangers so invited shall be permitted to take part in the proceedings, but not to vote. Invitation of Strangers.

Secretary and Treasurer's Duties.

30.—The Secretary, who shall also act as Treasurer, shall be appointed by and act under the direction and control of the Council, and shall be paid such salary as the Council shall determine. He shall attend all meetings, Council and General, and shall take minutes of the proceedings, and enter them in proper books provided for the purpose. He shall write the correspondence of the Institution and Council, read minutes and notices at meetings, report discussions, and, if required by the Council, prepare papers for reading and publication, and read papers and communications at the meetings. He shall receive all payments due to the Institution, and shall bank the cash in hand whenever it amounts to ten pounds. The bank shall be determined by the Council and the banking account shall be in the names indicated in connection with the Finance Committee. He shall keep a cash account book, general and detail, which shall on all occasions be open to inspection by the Finance Committee or by the Council. He shall keep a register of the names of members, so arranged as to distinguish all members whose subscriptions are in arrear. He shall also perform whatever other duties are indicated in the Bye-Laws of the Institution as appertaining to his department; and shall remain in office during the pleasure of the Council. He shall not vote on any resolution.

Finance Committee.

31.—The following Sub-Committees shall be appointed annually by the Council:—(1) A Finance Committee, to consist of seven persons, viz., one Past-President or Vice-President, who shall be Chairman; five Councilmen, and the Honorary Treasurer of the Institution; three of whom shall form a quorum. The Treasurer shall be empowered to pay all amounts due from the Institution which are under two pounds. All amounts of two pounds and upwards shall be paid by cheque signed by the Chairman of the Finance Committee (or in his absence, by the President or a Past-President), the Secretary, and the Honorary Treasurer. (2) A Reading Committee, to consist of six members of Council.

Payment of Accounts.

Reading Committee.

TRANSACTIONS.

32.—All papers shall be forwarded to the Secretary at least five clear weeks before the proposed date of reading. The Secretary shall submit them for approval to the Council, and on their general approval they shall be handed to the Reading Sub-Committee, three of whom at least, shall read the paper through. The Reading Committee shall be at liberty to strike out any parts which, in their opinion, ought not to be read. They may also make any suggestions to the author as to points which might with advantage be inserted or altered.

Papers to be submitted to Council.

Reading Committee.

33.—The papers read, and the discussions on them, or such portions of them as the Council shall select, shall be printed for distribution among the members, each of whom shall receive a copy. These Transactions shall be edited by the Secretary, in accordance with instructions of the Council, who shall have power to omit parts of discussion which may be foreign to the subject, or which it may be deemed undesirable to retain. Each paper shall bear the date on which it was read in General Meeting.

Printing Transactions.

34.—Copies of papers to be read during any session will be sent seven days before the date of reading to members who shall have applied to the Secretary for them, in writing, at the commencement of the session. The discussion on a paper shall not be considered closed on the evening on which it is read, but shall be open for renewal at a subsequent meeting, prior to the reading of the paper set down for that date.

Copy of Papers supplied to members before reading, etc.

35.—Proofs of the reports of discussions shall be sent for correction to the members who have taken part in the discussion, but must be returned to the Secretary within seven days of the date on which they were sent, otherwise they will be deemed correct, and will be printed off.

Proofs sent to members for Correction.

36.—The Council shall be at liberty to print as Transactions, either with the papers and discussions or separately, explanatory notes, etc., communicated after the reading or discussing of a paper. Such communications shall bear the date on which they shall have been received by the Secretary.

Liberty to Print Explanatory Notes.

37.—The Institution shall not be held responsible for the

Institution not responsible for statements.

statements and opinions advanced in any of the papers which may be read, or in the discussions which may take place at the Meetings of the Institution.

Copies of Transactions to be sent to members.

38.—Twenty copies of each paper and discussion shall be presented to the author of the paper, for private use, and one copy shall be sent to each member. When a paper is prepared by two authors, fifteen copies shall be presented to each. Duplicate copies of parts of the Transactions mislaid or lost by members cannot be supplied to them, except as provided for in Bye-Law 41.

Transactions not supplied to Members in Arrears.

39.—The Transactions shall not be supplied free to members whose subscriptions are more than one year in arrear.

Members not to receive Transactions till after First Payment.

40.—Any member elected at any time between the Annual General Meetings shall be entitled to copies of all the Transactions issued during the session to which his first subscription applies; but not until the subscription has been paid.

Transactions the Property of the Institution.

41.—The Transactions of the Institution shall be the exclusive property of the Institution, and shall be published only by the authority of the Council. Additional copies of papers required by authors for their private use can only be procured from the Secretary, at prices fixed by the Council from time to time, and these copies must contain the whole of the discussion following the papers, and be bound in the usual cover, with the addition of the following words:—"By permission of the Council," and "Excerpt Minutes of Proceedings." Duplicate volumes and copies of parts of the Transactions, if in print, can also be obtained from the Secretary, and shall be sold only by him, in such manner and at such prices as the Council shall have fixed.

Rule of Discussion.

42.—During a discussion upon any paper, no person shall be at liberty to speak more than once (except by way of explanation), nor for a longer period than ten minutes.

ACCOUNTS.

43.—The Council shall present the yearly accounts (up to the 31st of May preceding) at the October General Meeting of

each year, after they have been audited by a professional Accountant, appointed by the members at the General Meeting in May.

ALTERATIONS TO CONSTITUTION AND BYE-LAWS.

44.—Alteration in or addition to the Constitution and Bye-Laws may be made only by resolution of the members at the May General Meeting, after notice of the proposed alteration or addition has been announced at the previous General Meeting.

The resolution may be modified by the Council meanwhile, should they so desire; but in this case it shall be read at the May General Meeting in its original form before it is proposed in the amended form.

Such resolutions shall be stated in the notice calling the intervening Council Meeting, and also in the notice calling the May General Meeting.

Any member unable to be present at the meeting at which such alterations are to be considered, but who is nevertheless desirous of recording his opinion thereon, shall be allowed to vote by proxy, such proxies shall be in Form J in the Appendix, which may be had on application to the Secretary, and may be used by any member present at the meeting on behalf of the absent member, and counted by the Chairman as of equal value with votes given in the manner provided in Bye-Law 19.

THE LIBRARY AND READING ROOM BYE-LAWS.

1.—The Library and Reading Room shall be managed by a Committee, called the Library Committee, who shall have charge of all books, papers, specimens, etc., which may belong to the Institution. It shall consist of five members of the Institution, of whom at least two shall be members of Council.

2.—The books and other property of the Library shall be vested in the Trustees appointed by the Institution.

3.—The Library Committee shall be appointed annually, at the first meeting of the Council in each session, and its members shall be eligible for re-eleetion.

4.—The Secretary of the Institution shall be Librarian, and shall also act as Secretary to the Library Committee. Three members of the Committee shall form a quorum.

5.—The Library Committee shall be responsible for the binding and purchasing of books, periodicals, papers, etc., and for the expending of all money voted by the Council for its use. It shall appoint an attendant who shall act as Assistant Librarian. It shall make Bye-laws for the management of the Library, subject to the approval of the Council, and present an annual report to the first meeting of the Council held after the annual scrutiny of the books, referred to in Bye-law No. 13.

6.—Except when closed by special order of the Library Committee, or when the Council is sitting, the Library and Reading Room shall be open for consulting, borrowing, or returning books, every week day as follows:—On Monday, Tuesday, Thursday, and Friday from 10 a.m. to 12 noon, and from 1·30 to 9 p.m.; on Wednesday, from 10 a.m. to 12 noon, and from 1·30 to 5 p.m.; on Saturday, from 10 a.m. to 1 p.m., and from 3 to 9 p.m. The Rooms will be closed on Christmas Day, New Year's Day, and Good Friday, Monday and Tuesday in Easter week and Whit week, and from the first to the second Saturday in March of each year, as mentioned in Bye-law No 13.

7.—Books shall not be lent to any persons except Members, Associates, or Graduates of the Institution, but a person entitled to borrow a book may send a messenger with a signed order for it.

8.—Each member shall be entitled to introduce a friend to the Reading Room, whose name shall be written in the visitors' book, together with that of the member introducing him.

9.—The books marked with an asterisk in the Catalogue shall be kept only for consultation in the Library, and shall not be lent. Pending the preparation of a Catalogue, the Librarian shall be instructed by the Committee as to which books shall be withheld from circulation.

azines, or pamphlets shall be issued for
r they have been bound and added to the

rarian shall keep a register in which he him-
dant shall enter the titles of the books lent, the
the name of the borrower, and the date of the
ook to the Library. The borrower of the book
of his order shall initial the entry of such borrow-
Librarian or the attendant shall initial the date of
of the book.

No person shall borrow or have in his possession at one
re than two volumes belonging to the Library.

.—No member shall retain a book longer than fourteen
excluding the day of issue. He shall be responsible for
afe return of the book, and if it be damaged or lost he shall
good the cost of such damage or loss.

13.—All books belonging to the Library shall be called in
inspection and the lending out of books shall be suspended
om the first to the second Saturday of March, inclusive, of each
year, and members shall be required by an intimation inserted
in the notice calling the preceding meeting of the Institution to
return all books in their hands before the period mentioned.

Members failing to comply with this injunction shall pay a fine of two shillings and sixpence.

14.—Members are requested, when in the Reading Room or Library, to contribute to the general comfort by carefully abstaining from loud talking, noise of any kind, and from smoking.

15.—Any member being twelve months in arrears with his subscriptions to the Institution shall not be at liberty to use the Library or Reading Room after the commencement of the first session following.

N.B.—The foregoing Rules may be amended at any time by the Library Committee with the sanction of the Council.

APPENDIX TO BYE-LAWS.

FORM A. (BYE-LAW 1.)

Name (in full)

Profession or Occupation and where Employed

Address

being desirous of admission into the North-East Coast Institution of Engineers and Shipbuilders, we, the undersigned, propose and recommend that he shall become*

thereof. We know him to be†

and eligible for the proposed membership.

A Member, Associate, or Graduate.

† A Principal, Manager, or Draughtsman, etc See Articles V., VI., and VII. of Constitution.

	FROM PERSONAL KNOWLEDGE.	SECTION OF MEMBERSHIP.
Proposed by		
Supported by Three Members or Associates.		

Dated this day of

(When a Graduate is proposed the age last birthday should be stated.)

FORM B. (BYE-LAW 2.)

A. B. [Christian Name, Surname, Occupation, and Address in full] being at present a of the North-East Coast Institution of Engineers and Shipbuilders, and upwards of twenty-four years of age, and being desirous of becoming a of the said Institute, we, the undersigned [Members or Associates], recommend him, from *personal knowledge*, as a person eligible for the proposed Change of membership, because—

(Here specify distinctly the Qualifications of the Candidate according to the spirit of the Rules of the Institution.)

Signed _____ } Three [Members or Associates.]

_____

_____

Dated this day of 18

FORM C. (BYE-LAW 3.)

BALLOTING PAPER FOR MEMBERSHIP.

The Council having considered the recommendations for Membership of the following gentlemen, present them to be balloted for, viz.:—

Member, Associate, or Graduate.	Occupation.	Address.	Nominated by.	Supported by Three Members or Associates.

Strike out the names of such persons as you desire shall *not* be elected, and forward the list by post to the Secretary, or personally place it in the ballot-box at the Meeting.

FORM D. (BYE-LAW 4.)

Sir,—I am directed to inform you that on the day of you were elected a of the North-East Coast Institution of Engineers and Shipbuilders, but, in conformity with Bye-Law 4, your election cannot be confirmed, nor your name be added to the roll of membership, until you have paid your first annual subscription, the amount of which is £ : : , or, at your option, the Life Composition of £ : : .

Payment may be made to the Treasurer, Mr._____

Address_____

I am, Sir,

Yours faithfully,

Secretary.

Dated 18

N.B.—In case of a Graduate, strike out "*or, at your option, the Life Composition of £ : : .*"

FORM E. (BYE-LAW 9.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to draw your attention to Bye-Law 6, and to remind you that the sum of £ of your annual subscriptions remains unpaid, and that you are in consequence in arrear of subscription.

I am also directed to request that you will cause the same to be paid without further delay, otherwise the Council will be under the necessity of exercising their discretion as to using the power vested in them by the Rule above referred to.

I am, Sir,

Yours faithfully,

Secretary.

FORM F. (BYE-LAW 9.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to inform you that in consequence of non-payment of your arrears of subscription, and in pursuance of Bye-Law 9, the Council have determined that unless payment of the amount (£) is made previous to the day of next, they will proceed to declare that you have ceased to be a member of the Institution.

But, notwithstanding this declaration, you will remain liable for payment of the arrears due from you.

I am, Sir,

Yours faithfully,

Secretary.

FORM G. (BYE-LAW 10.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to inform you that they feel it their duty to advise you to withdraw from the Institution, or otherwise they will be obliged to act in accordance with Bye-Law 9 (or 10, as the case may be.)

I am, Sir,

Yours faithfully,

Secretary.

FORM H. (BYE-LAW 11).

BALLOTING LIST.

PRESIDENT.—ONE NAME only to be returned, or the vote will be lost.

——— President for the current year (eligible for re-election.)*

——— } New Nominations, from whom to select ONE.

VICE-PRESIDENTS.—NINE NAMES only to be returned (including the six who remain in office), or the vote will be lost.

——— } Six Vice-Presidents remaining in office, whose seats are NOT vacant.

——— } Three Vice-Presidents retiring, and NOT eligible for re-election.

——— } New Nominations, from whom to select THREE names.

TREASURER.—ONE NAME only to be returned, or the vote will be lost.

——— Treasurer for the current year, eligible for re-election.

——— } New Nominations, from whom to select ONE.

COUNCILMEN.—FIFTEEN NAMES only to be returned, including the ten who remain in office.

——— } Ten Councilmen remaining in office. These do not require to be voted for at this election, as their term of service has NOT yet expired.

——— } Five Councilmen retiring, and NOT eligible for re-election.

——— } New Nominations from whom to select FIVE.

* To be crossed out before issue, when the President is not eligible for re election.

N.B.—(*a*) The names of those who remain in office will be counted in the total number required without being re-written by the voter.

(*b*) Any list having either MORE or LESS than the required number of names voted for in any section will be disqualified for that section.

(*c*) Votes as President for a person who is not elected will count for him as a Vice-President.

(*d*) Votes as Vice-President, or Treasurer, for persons not so elected, will count for them as Councilmen, unless they have just completed a term of office in that capacity.

(*e*) This list, duly filled in, may be returned to the Secretary by post, or handed to him, so as to be on the Council table before the commencement of the scrutiny, which is appointed to take place in the Council Room, at 8 p.m., on 18

(*f*) A copy of this list shall be posted at least Seven Days previous to the Annual Meeting to every Member and Associate, who may erase any name or names from the list and substitute the name or names of any other person or persons eligible for such respective offices, but the number of persons on the list after such erasure or substitution must not exceed the number to be elected to the respective offices.

Secretary.

(FORM J. (BYE-LAW 44.)

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FORM OF PROXY

FOR VOTES ON ALTERATIONS TO CONSTITUTION OR BYE-LAWS.

I,.....being [an Honorary Member, Member, or Associate] of the above Institution, do hereby appoint Mr..... who is [an Honorary Member, Member, or Associate] of the same Institution, to act as my Proxy, and record my Vote at the General Meeting of the Institution, to be held on the.....day of ....., 18....., and at any adjournment thereof.

Signature.....

Address.....

.....

.....*Secretary.*

NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

SIXTH SESSION, 1889-90.

PROCEEDINGS.

ANNUAL GENERAL MEETING, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON MONDAY EVENING, OCTOBER 21st, 1889.

F. C. MARSHALL, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the Closing Business Meeting of the last session, held in Newcastle-upon-Tyne, on May 13th last, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. Alex. Taylor and James Patterson to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Barnett, James Rennie, Lilybank House, Johnston, N.B.

Beardmore, William, Messrs. Wm. Beardmore & Co., Parkhead Forge, Glasgow.

Berkley, William, Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne.

Booth, Arthur Spence, 77, Thornton Street, West Hartlepool.

Churchill, James Dixon, 23, Leadenhall Street, London, E.C.

Cooper, Nusserwanji Naoroji, Tuths Agari, Chawpati, Malabar Hill, Bombay, India.

Dykes, John, Lloyd's Registry of Shipping, Barrow-in-Furness.
Eltringham, Joseph T., Stone Quay, South Shields.
Harrison, Alfred, 13, Nelson Street, Sunderland.
Head, Jeremiah, Middlesborough-on-Tees.
Jones, Frederick Robert, Sirmoor State, Nahan, Punjaub, India.
Middlemass, Thomas, 3, Albert Place, Norton Road, Stockton-on-Tees.
Rayner, Thomas, 24, Side, Newcastle-on-Tyne.
Reed, Joseph, 25, Side, Newcastle-on-Tyne.
Robson, George, 9, Wellington Terrace, South Shields.
Scott, George Innes, 9, Queen Street, Newcastle-on-Tyne.
Zeeman, J. H., c/o Messrs. The Maas Co., Limited, Rotterdam.

ASSOCIATE.

Crosier, Edward James, 9, Lincoln Terrace, Gateshead-on-Tyne.

GRADUATE.

Smith, Launcelot Eustace, 8, Wilberforce Street, Wallsend-on-Tyne.

The Council's Report and Treasurer's Statement for last year was read by the Secretary, and submitted to the meeting for adoption.

COUNCIL REPORT.

(FIFTH SESSION.)

THE fifth session has been an eventful one in the history of the Institution. The financial position of the Institution is extremely satisfactory, as will be seen from the balance sheet submitted with this Report. This is largely due to the alterations made at the close of last session in Articles V. and VII. of the Constitution, by which the subscriptions of certain classes of members were increased, together with the increase in the number of members during the year.

In response to the kind invitation received from the members resident in the Hartlepools, the Institution visited the Hartlepools on the afternoon of Saturday, October 20th, 1888. The various shipbuilding and engineering establishments were thrown open for inspection to the members, who were afterwards entertained by the Local Reception Committee at a dinner presided over by the Mayor of West Hartlepool (William Gray, Esq.), supported by the Mayor of Hartlepool (Thomas Richardson, Jun., Esq.). In the evening the General Meeting was held, presided over by the President (F. C. Marshall, Esq.), at which an important paper on "The Use of Machinery in Construction," by John Price, Esq., was read, and an interesting discussion ensued. The meeting altogether was a most successful one.

It having been resolved that suitable Offices should be procured for the Institution, rooms were taken on the first floor of No. 4, St. Nicholas' Buildings, Newcastle-upon-Tyne, which were entered by the Institution on November 11th, 1888. These consist of a Library and Council Room, Reading Room, and Secretary's Office. The cost of furnishing these rooms is being met by donations received from the members alone, no moneys having been taken from the General Fund of the Institution. A code of Bye-Laws has been drawn up for the management of the Library and Reading Room, and for some months past the rooms have been open daily for the use of members.

During the session the following resolution was passed by the Council:—"As the Institution now possesses a room suitable for the purpose, meetings of Graduates shall be held during each session, as may be arranged by the Council, to read and discuss papers and other matters

connected with shipbuilding and engineering, it being understood that a member of the Council shall take the chair at each meeting." A meeting of the Graduates was convened by the President to take action upon this resolution, but the number of Graduates who attended was so small that it was agreed nothing should be done till the following session. It is now hoped that the Graduates will avail themselves of the advantages offered, and the Council will be pleased to consider any suggestions they may wish to make.

On June 11th, 1889 (Whit-Tuesday), the members and their friends visited the Forth Bridge, then under construction. The trip proved a most enjoyable one, and it is hoped it will be the prelude to similar annual social gatherings.

During the session the following papers were read:—

1.—"The Use of Machinery in Construction." By Mr. John Price.
2.—"A New System of Shipbuilding to facilitate the application of Machine Riveting to Shell Plating." By Mr. Johan Johnson.
3.—"A New Wave Motor." By Mr. J. A. Rowe.
4.—"The Structural Strength of Cargo Steamers." By Mr. G. Bergström.
5.—"The Development of the 'Well-Deck' Cargo Steamer." By Mr. G. W. Sivewright.
6.—"Corrosion and Pitting in Marine Boilers." By Mr. J. B. Dodds.
7.—"The Proper Capacity of Air Pumps." By Mr. J. H. Hamilton.

The following additions have been made to the list of members:—1 Life Member, 108 Ordinary Members, 26 Associates, 12 Graduates, and 7 Graduates have been raised to the rank of Members. The Institution has to regret the loss by death of two of its Members—Mr. G. H. Garrett and Mr. Thos. Robson. It has also lost by resignations, gentlemen leaving the district, and from other causes, 25 Members, 4 Associates, and 3 Graduates. The number of names now enrolled is 3 Honorary Members, 5 Life Members, 583 Ordinary Members, 1 Life Associate, 89 Associates, and 45 Graduates, making a grand total of 726 Members.

The property of the Institution has been vested in three Trustees—Messrs. William Boyd, W. Theodore Doxford, and Francis C. Marshall.

In order to meet the contingencies necessarily arising in the working of such an Institution as this, it has been requisite to make further alterations in the Articles of Constitution and the Bye-Laws, as follows:—

(*a*) Owing to the large influx of Members from the Hartlepool district the number of representatives on the Council list has been increased by the addition of three Vice-Presidents, making nine in place of six, and Articles IX. and X. have been amended accordingly.

(*b*) In Article VII., relating to the Graduates, the age has been extended from 21 to 24 years.

(*c*) In Bye-Law 6 an important alteration has been made by the insertion of the following clause:—"Any Member, Associate, or Graduate wishing to retire from the Institution shall continue to be liable for his annual subscription until he shall have given formal notice of his retirement to the Secretary, which notice must be given on or before the 31st August in each year."

The Council regrets having to report that the sum of the subscriptions in arrears has somewhat increased. It is hoped that those members whose subscriptions for the previous sessions are still unpaid will at once remit the amount to the Secretary.

Another great source of inconvenience is due to the forgetfulness of some of the members to advise the Secretary of change of address; and from the published list of members it will be seen there are many whose names still stand in the list, but of whose present abode the Secretary has no knowledge.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

STATEMENT OF RECEIPTS AND PAYMENTS FOR SESSION ENDING 31ST MAY, 1889.

Receipts.

		£ s. d.	£ s. d.
To Balance from last Account—			
At Banker's		20 1 1	
In hand		2 10 9	
			22 11 10
„ Subscriptions received for Session, 1888-9—			
180 Members at £2 2s.	£378 0 0		
90 Associates „ £1 1s.	94 10 0		
360 Members „ £1 1s.	378 0 0		
42 Graduates „ 10s. 6d.	22 1 0		
		872 11 0	
„ Arrears for Sessions 1886-7 and 1887-8—			
12 Members at £2 2s.	£25 4 0		
19 Members „ 10s. 6d.	9 19 6		
5 Associates „ £1 1s.	5 5 0		
3 Graduates „ 5s. 0d.	0 15 0		
		41 3 6	
			913 14 6
„ Life Member (J. R. Pascoe)			21 0 0
„ Transactions sold this Session			37 16 11
„ Amount received this Session for Transactions sold 1885-6			0 10 6
„ Library Fund—			
Donations		136 18 6	
Press sold		2 0 0	
Balance from Forth Bridge Excursion		1 8 6	
			140 7 0
			£1,136 0 9

Payments.

	£ s. d.	£ s. d.
By Transactions and Papers—		
Lithographing	131 5 6	
Printing and Binding	150 1 9	
		281 7 3
„ Stationery and Circulars	73 3 9	
„ Reporting	23 0 0	
„ Advertising	2 19 6	
„ Rents—		
Offices, 9 months	45 9 0	
Lecture Rooms	6 4 0	
„ Rates, Gas, and Insurance	8 1 9	
„ Fees to Hall Keepers	1 1 0	
„ Salaries—		
Secretary	120 0 0	
Assistant Librarian, 6 months ...	12 10 0	
„ Postage Stamps, Post Cards, and Parcels	69 2 4	
„ Secretary's Expenses	3 16 8	
„ Office Expenses, Coals, Cleaning, &c. ...	17 1 11	
„ Hanging Drawings	1 12 10	
„ Rent for Measured Mile Posts	3 3 0	
„ Auditor's Fee	1 11 6	
		388 17 3
„ Library Fund—		
Office Furniture, Safe, &c.		149 4 9
„ Balance—		
At Banker's	315 8 2	
In hand	1 3 4	
		316 11 6
		£1,136 0 9

The Balance Sheet.—31st May, 1889.

Liabilities.	£	s.	d.
To Capital	705	12	0
	£705	12	0

Assets.	£	s.	d.	£	s.	d.
By Sundry Debtors				8	6	0
„ Subscriptions in arrear—						
Session, 1887-8	14	8	6			
„ 1888-9	68	15	6			
				83	4	0
„ Stock of Transactions, valued at				147	10	6
„ Office and Library Furniture, Safe, &c.				150	0	0
„ Cash at Bankers	315	8	2			
„ „ in hand	1	3	4			
				316	11	6
				£705	12	0

Audited and Certified,

R. W. SISSON, F.C.A.

Newcastle-upon-Tyne, 27th September, 1889.

The PRESIDENT said it was his privilege to move the adoption of this Report, and, in doing so, he would like to make one or two remarks. In the first place, he thought they would all agree that the Institution was to be sincerely congratulated upon its financial position. They began last year with a balance of £22; they finished the year with a balance of £316. It was feared, if they remembered, that the increase of subscriptions of certain members would rather militate against the Institution, and that many would be disposed to resign on account of the increase. This was found, however, not to be the case, as, in reality, there had been very few resignations, and the increase for the year in the membership, after deducting the members who had resigned and removed to other places, and who were deceased, was 113. They had now, for an Institution only five years' old, a grand total of 726 members. He thought they would agree with him that this was a very satisfactory state of things, and promised well for the future of the Institution.

He would recall to their recollection the very satisfactory and interesting meeting that they had had at Hartlepool. There was only one impression of that meeting, that it was altogether most satisfactory, and such as could be repeated with great advantage at as early a period as possible. Up to the present time they had no positive offer of a similar invitation. It may be that they would be disposed to reciprocate the kindness of their friends and invite them over here, and he was sure they would accord their readiness to that, as readily as they went to Hartlepool.

The visit to the Forth Bridge was an unclouded success.

Let him urge upon them the question of the Library and Furnishing Fund. The expenditure of this fund altogether amounted to £200, or thereabouts, all of which was subscribed, with the exception of £25 or £30 for the binding of books, in order to place them perfectly clear to begin with. Such an amount should not stand in the way in an Institution of this kind. This was a voluntary subscription, and he hoped something would be done. He ventured to send a circular out about a month ago, to which they had received eight responses amounting to £11. He hoped the membership of the Institution would take care that this meeting did not get over without that £25 being contributed. Many gentlemen could do it with a single stroke of the pen and cost them next to nothing, and he hoped they would do it for the benefit of posterity and the comfort of the present members.

The Report mentioned the meeting of Graduates. Their President and Mr. Macoll met so many of the Graduates as turned up at the

meeting—only four came—so there was no hope of forming a Graduate section out of four Graduates; but it was his intention to at once take such steps as could be taken to have a meeting of the Graduates, in order that they might form what he deemed to be this very important section of the Institution. Their young men needed all the help they could get, and he knew no better than the help to be afforded by such meetings as were intended to be held by the Graduate section for the reading and discussing of papers. He was quite sure they had all felt the benefit of meetings of this nature in the past, and nothing gave a young man a greater advantage than the attempt to write a paper and then to speak upon it, or to speak upon a paper read by someone else. In order to acquire facility in speaking, it was very necessary they should have practice, and these meetings would afford the opportunity of obtaining practice in that, as he should call it, very valuable art.

The papers of the last session were of a very satisfactory character. He need only allude to the paper read by his friend, Mr. John Price, as most valuable and interesting, and calculated to be of great service to both old and young members of the Institution, and others, too, notably Mr. Sivewright's paper on the Well-deck Ships, and Mr. Bergstrôm's. He hoped this session they should have a succession of papers of a similar character.

The various modifications in the Constitution and Bye-laws of the Institution mentioned in the report were found to be very necessary. For instance, the question of the increase of the number of Vice-Presidents: they felt, seeing they were extending their boundaries, and that Hartlepool was coming in so satisfactorily and earnestly into the Institution, it was very important that they ought to have Vice-Presidents from that neighbourhood as well as another from Sunderland, and they would notice in the reading of the list of Vice-Presidents that Mr. Wm. Gray and Mr. Richardson, of Hartlepool, and Mr. John Dickinson, of Sunderland, were now Vice-Presidents of this Institution. By this means they hoped to extend their influence, and also the usefulness of the Institution to its members.

He need not raise the question of the defalcation of their members in not paying up their contributions. It had been so often raised, and it did not seem creditable they should have so large a balance of unpaid subscriptions. The members who were in arrears, he hoped, would take care to forward to the Secretary what was due. With these remarks, he begged to move the adoption of the Report.

Mr. H. Macoll thought a few minutes might be devoted to the question of the general Report. They had an animated discussion at the beginning of last session about the raising of the subscriptions, and various suggestions were made as to reducing the cost of postage, lithographing, and so on, and grave doubts were expressed as to the effect of increasing the subscriptions on the prosperity of the Institution. If the members looked through the last five years' Transactions they would find they had averaged something like £460 per annum for lithograph printing, engraving, postage, and such like charges. This was quite enough to show that with the great bulk of the members paying 10s. 6d. each per annum, the Institution never could have been carried on successfully.

It was to be hoped that the Graduates would show up in greater numbers. It was, no doubt, rather a difficult question; they were widely scattered, and the great bulk of them were attending classes, and others were working overtime. He was afraid, until the present briskness slacked down a little, they would not make much progress with the Graduates. Still, they were desirous of meeting with them and seeing what could be done in the matter, and a meeting would be called shortly.

There was another matter he thought they ought to consider soon; that was, having a meeting or meetings in the Hartlepool district. It was a matter they ought to deal with very soon. If the members did not get a meeting or two in the course of the year, they would lose touch; and, as the trains were at present arranged, there was no chance of the Hartlepool members leaving home and getting to Newcastle and back on the same evening. Meetings held earlier, or on a Saturday afternoon, would meet the case. If none of the members desired to say anything further, he had much pleasure in seconding the adoption of the Report.

The Report was cordially received and adopted.

Donation to the Literary and Philosophical Society's Building Fund.

The President said he had now to move, on behalf of the Council, "That the sum of twenty guineas be given from the funds of this Institution as a donation to the Building Fund of the Literary and Philosophical Society of Newcastle-upon-Tyne." He hoped they would not think they were getting extravagant all of a sudden, and that because they had a balance in hand they were trying to get rid of it as soon as

possible. This came fortuitously just at the time of their meeting. They were aware the Literary and Philosophical Society had granted them the use of their rooms for five years free of charge, and that the society had recently been put to very great expense owing to the North-Eastern Railway Company wanting part of their ground, and the building being found, when touched, falling into decay. They had to go to great expense in repairing their roof, so much so that the expense incurred had far exceeded what the railway company allowed them for what they took. They had applied to them and other Institutions, and also to private aid, for contributions for the liquidation of the debt incurred. He begged to move that they grant this sum of twenty guineas out of the funds of the Institution as a donation.

Mr. Wm. Boyd said, he had much pleasure in seconding this proposal, and he did so with some appropriateness. One reason that should carry weight with them was this, that one could quite understand the society referred to (the Literary and Philosophical) having great pleasure in granting them the use of its rooms now that they were in full maturity as an important Institution, but he begged to remind them that the Literary and Philosophical granted them the use of the room without question when they were in their infancy. They might never have reached the full manhood of which they could now boast that day, but for the encouragement that they received by the use of that room five years ago. That encouragement was invaluable to the Institution, therefore, he thought, their feelings of gratitude for what the Literary and Philosophical did for the Institution in its early days should certainly induce them to support most cordially the resolution moved by the President.

The proposal on being put to the meeting was cordially accepted.

Postponement of Presidential Address.

The President said it had been the custom of this Institution, as it was of most institutions of this kind, that its President should deliver an address which would be of some interest to this Institution. Their first President, Mr. Boyd, in a very admirable address he delivered in his second year of office, said there were three kinds of addresses—the historical address, the technical address, and the suggestive address. He heard that day that there was another kind of address, and that one of the leaders of their public opinion had denominated an address he had the

honour of delivering to them last year as "a kind and emotional address." He was not going now to give them either the one or the other, but a strictly personal address, and he asked them to bear with him in the few seconds he did it. As they were aware—many of them were aware—he had been undergoing an illness of rather severe and painful character for a good many months, consequently he found himself absolutely unable, either mentally or physically, to undertake the preparation of any address. In fact such an effort was strictly forbidden, and he therefore asked them to excuse the omission on this occasion, and he promised them, as soon as he could, to deliver the presidential address of the session, which probably would not be very worthy of their hearing, but such as it was he would render to them at the fit and proper time. He had now to call upon Mr. Macarthy to read his paper.

Mr. G. E. MACARTHY then read the following paper, entitled "Notes on the Surveying and Classification of Shipping."

NOTES ON THE SURVEYING AND CLASSIFICATION OF SHIPPING.

By G. E. MACARTHY.

[Read before the Institution in Newcastle-on-Tyne, on October 21st, 1889.]

The writer will not attempt to deal with this question in a technical or scientific manner for the very sufficient reason that he does not possess the requisite knowledge.

Ever since the beginning of the human race, or at least so far as we can trace back its history, water has formed an important part in the transmigration of peoples and in the transport of their wants. We read in Genesis how the ark was built by Noah. How it was pitched within and without. It is rather remarkable that the dimensions of this ark should so closely correspond to our latest type of cargo vessels known as tramps, viz.: length 300 cubits, breadth 50 cubits, depth 30 cubits. Taking the cubit to be 20 of our inches, and as, no doubt, her coefficient would be large, her gross tonnage would be about 18,000 tons, or about the size of the "Great Eastern." Coming down to later times we find that the Phœnicians were the great traders of the world. Hiram, king of Tyre, doing good service to Solomon in providing him with material for the building of the Temple and other buildings in Jerusalem, and lending him sailors for his trading expeditions to India; indeed it is recorded that the Phœnicians even found their way to Britain for tin, a great feat in navigation in those days. How their ships were built we are unable to state, but no doubt they were "staunch, strong, and in every way fitted for the voyage." The Greeks follow, then the Romans, the galleys of the latter doing a great part in the work of conquest. The Venetians and other Italian republics had their day, then Spain, and lastly England became mistress of the seas.

Of the remote beginning of marine insurance, with which the subject of classification is so closely allied, little is known. The Phœnicians, Greeks, and other ancient peoples we are told were in the habit of guarding themselves against risks of maritime enterprise. "Nautical

insurance," as Gibbon terms it, was common to the Romans. In the Middle Ages it was carried on regularly in the Italian republics, which even went so far as to regulate by law the "load line."

The classification of British shipping appears to have commenced about the year 1726. An advertisement in the *London Gazette* of 18th February, 1668, states that "Ships' Lists" were kept at Lloyd's Coffee House, owned by a Mr. Edward Lloyd, and these lists contained the germ of the present well known "Lloyd's Register." The oldest copy of a register of shipping in the library of Lloyd's office bears date of 1764. This register contains the vessel's name, master, port, tonnage, when and where built, owners, class, distinguished by the vowels A, E, I, O, and U, with the letters G (good), M (middling), and B (bad), and date of survey. From this has been gradually developed the complete Lloyd's Register of to-day with its 100 A1 classification downwards, and all its various particulars as to outfit, etc. It would take up too much time to trace all the various changes that have taken place in this register, but "A1 at Lloyd's" is a household word.

The register, it is said, was established by underwriters for their sole use. The members were bound under penalties not to communicate the contents, or allow the register to be seen by outsiders. In 1798, the committee for conducting the affairs consisted of eleven gentlemen, who held their meetings at Lloyd's Coffee House. At this time a new style of classification was introduced, which being scarcely equitable in its operation, ultimately led to the formation of a new register, and it is interesting to notice the low estimation in which vessels built in the northern ports were held, not only at this time but long after. The dissatisfied shipowners, failing to obtain satisfaction, several of them started "The New Register Book of Shipping" in 1799, and this became known as the "Red Book" or Shipowners' Register, the old one being known as the "Green Book" or Underwriters' Register.

It was not until 1822 that we find any record of a steamship in the register—the "James Watt," 294 tons, built at Greenock in 1821, and classed A1. The distinction, however, of possessing the first practical steamboat was reserved to Lord Dundas, who in 1801 had a vessel constructed which towed two loaded vessels 16½ miles in six hours. The idea was now fairly started, and in 1811 the well-known "Comet" was built. Indeed, to such importance had the subject grown in 1817, that a committee of the House of Commons sat in that year. As a result of their investigations all steamboats were required to be registered, and their boilers to be of wrought iron or copper. It would thus appear that the committee of the Register Book were far behind

the times in admitting steamers to classification. In 1832 the book contained 100 steamers. In 1834 there was a fusion of the two registers, and the rules then underwent considerable alterations. The permanent committee was composed of eight merchants, eight shipowners, and eight underwriters, together with the chairman of Lloyd's and the chairman of the General Shipowners' Society. These gentlemen were drawn from the shipping community of London alone, the outports having no direct voice in their choice. To conduct the surveys prescribed by the rules of the new committee, a staff of surveyors was appointed, numbering sixty-three in all, of whom thirteen were exclusively the servants of the society, and these latter were distributed in the different ports of the United Kingdom.

Bristol	1
Glasgow and the Clyde	1
Hull and the Humber	2
Leith and the Firth of Forth	1
Liverpool	2
London	3
The Tyne	1
Sunderland	2
	13

In 1838 "The Liverpool Register of Shipping" was started, but in 1844 "Lloyd's" amalgamated with it, giving Liverpool a "branch" committee, consisting of twelve members elected by the Liverpool Underwriters' and Shipowners' Associations in equal proportions, which "branch" exists to this day.

The first iron steamer entered in Lloyd's Register appears to have been the "Sirius," 180 tons, built in London in 1837, but it is not until 1844 that the committee decided to class iron steamers, and in 1855 the shell plating for vessels of 3,000 tons was required to be one inch thick, and the frames to be spaced not more than sixteen inches apart.

Dissatisfaction existed then, and subsequently became so intensified, as to the classification and surveying of iron vessels, that in 1862 was established the "Liverpool Underwriters' Registry for Iron Vessels," or "Red Book," with an influential representative committee, under whose rules considerable changes were made in the scantlings as compared with Lloyd's. This registry attained considerable success under an efficient staff of surveyors, and its classifications were accepted by underwriters, shipowners, and merchants as freely as Lloyd's. However, it met the fate of its predecessors, and in 1885 it also was absorbed by its older rival, but with this difference, that its distinctive classifications and its

surveyors were retained; but there is reason to think that this distinction will not have a long life. It will thus be seen that there have been three epochs of dual registers followed by amalgamations—viz., 1799 to 1834, 1838 to 1844, and 1862 to 1885.

As a result of pressure from without, the constitution of Lloyd's to-day is as follows, viz. :—

A Chairman.
A Deputy Chairman.
A Chairman of Sub-Committee of Classification.
21 Members elected in London.
The Chairman of the Committee of Lloyd's.
The Chairman of the Shipowners' Society.
8 Members of the Liverpool Committee.
4 „ for Glasgow.
1 „ „ Greenock.
1 „ „ Leith District.
1 „ „ Cardiff District.
1 „ „ Bristol.
1 „ „ Hull.
2 „ „ Hartlepool District.
2 „ „ Sunderland.
3 „ „ Tyne District.

In all 50 members, and in addition there is the Liverpool "branch" committee, consisting now of 17 members (eight of whom are on the London committee), and who seem to have a semi-independent action. The permanent surveyors of the society for the United Kingdom numbered 21 for London, and 94 for all the outports. The accumulated capital and annual income of the society is not easily ascertainable; but judging from the abatement of about £6,000 per annum which has been recently granted in the survey fees, etc., it must be very considerable.

Lloyd's Register of 1888–9 gives classed vessels as follows:—

	British.		Colonial.		Foreign.		Total.	
	No.	Tons.	No.	Tons.	No.	Tons.	No.	Tons.
[illegible]	2,905	3,845,361	98	79,581	703	985,450	3,706	4,900,392
[illegible]	496	984,369	58	63,399	149	217,144	703	1,264,912
[illegible]	1,483	1,781,152	48	43,037	156	141,482	1,689	1,965,671
[illegible]	88	135,413	...	...	9	10,515	97	145,928
[illegible]	1,468	330,199	132	63,550	255	140,562	1,855	534,311
[illegible]	[illegible]	[illegible]	336	249,567	1,272	1,495,153	8,050	8,821,214

Next in importance to Lloyd's Register we have the "Bureau Veritas," and the writer will not weary you with a long history of this old society. It was established at Antwerp in the year 1828 under the modest title of "Office for Maritime Insurance Information," and in many respects its system of surveying and classification closely resembles Lloyd's. Like the London society it was instituted for the use of underwriters, to enable them to estimate the values of the various risks that were offered to them. The information furnished by this office, which in the following year adopted its present title of "Bureau Veritas," was first in the form of a monthly list, but the following year it assumed its present form of an annual "Veritas Register." In 1832 the society was removed to Paris, at No. 8, Place de la Bourse, in the same building where it now holds its sittings.

The form of the Veritas Register has been gradually modified to suit the times, like its London competitor, to which its rules and classifications closely approximate. It seems, however, to have soon obtained a much wider and international character. Indeed, it is said that in some of the more distant parts of the globe its certificates of classification are better known, and therefore more appreciated than Lloyd's.

The early London method of classification, and which existed for a long time, had the grave defect of being based solely on the age of the vessels, an absolutely false principle, and the Bureau Veritas claims the merit of discovering and remedying this defect by the adoption of a system of classification based upon the actual condition and value of the hull and equipment, and it is said that the alterations in Lloyd's Register which were adopted after the fusion of 1834 were inspired by the rules of the Bureau Veritas.

About the year 1867 the Bureau Veritas began to lay down rules for the construction of iron vessels and their machinery, and later on the conditions relating to mild steel used in marine work, and about 1884 those relating to the triple and quadruple expansion engines. The classifications, as set out by numerals, as 3/3.1.1, 5/6.1.1, 5/6.2.1, etc., is a mode which for clearness commends itself to one's mind as an improvement upon the Lloyd's system of mixing up vowels and numerals; the code as to trade, such as coasting (*petit capotage*), European (*grand capotage*), Atlantic, long voyage (*long cours*), is also useful.

The surveyors on the staff number 250, distributed in the various shipping centres, and are men of experience and quite up to the latest novelties in shipbuilding, engines, etc.

The Veritas Register for 1889 gives the following entries of classed vessels, viz. :—

	Steamers.		Sailing Vessels.		Total.	
	No.	Tons.	No.	Tons.	No.	Tons.
British	110	176,873	903	726,771	1,013	903,644
German	386	469,877	1,546	567,985	1,932	1,037,852
French	265	379,520	1,347	230,309	1,612	609,829
American	69	140,241	690	664,707	759	700,948
Various	543	491,268	3,859	1,432,539	4,402	1,923,835
Totals	1,373	1,657,779	8,345	3,622,311	9,718	5,176,118

The nationalities represented number over thirty-three. British tonnage heads the list with sailing vessels, and stands third in steam. Germany is first in steam, and third in sailing vessels.

There are many other registers extant, but it is needless to name them as they are almost entirely of a local character. For many of the foregoing statements and figures, I am indebted to the *Annals of Lloyd's Register*, published in 1884, in commemoration of the jubilee of that society, a copy of which is in the library of our Institution, and to the registers named.

The object of the writer in bringing this subject before the Institution is a desire to elicit its opinion as to the practicability of establishing a "North-East Coast Register of Shipping," and, if practicable, whether such a register would benefit the shipping interest of our district.

In summing up these remarks the writer wishes it to be understood, in the first place, that he distrusts monopolies. Lloyd's monopoly is in many respects objectionable. It is slow, uncertain, and very costly in its working. Its surveyors, no doubt, are men of ability and intelligence, but in matters of any importance they have no power, reference must be to a committee sitting in London (many say it is a one man committee). Take, for instance, the petroleum tank steamer question. How difficult must have been the task of the shipowner, shipbuilder, and engineer before they worked the oracle at White Lion Court. Then take the well-deck steamer question, and note at what cost of time and labour, journeying to and fro, and petitioning, these scientists were instructed as to what was a safe load-line, and then imagine the sim-

plicity of dealing with a registry located at our shipyard doors. Take now a much smaller matter. A steamer known to be thoroughly staunch and extra strong (she was proved so in the sequel) required a periodical survey. The surveyor, acting honestly on the letter of his instructions, ordered every stick of wood ceiling, etc., out of her; vessel to be cleared of everything to the bare iron; holes to be drilled until the entire hull would have been riddled like a sieve; then these holes were to be gauged; plans submitted to the committee, who would examine same and state what next would be required. Aghast, the owner asked how long they would detain the steamer, and was informed that five or six weeks might end the business. In desperation the owner withdrew her and classed her in Veritas Register, obtaining her original highest A1 class, completing the work in seven days. Had a committee been sitting in Newcastle this matter would have been settled in twenty-four hours or less.

Taking the tonnage built during the last twenty-five years in the ports of the Tyne, Wear, and Tees, calculated by the excellent statistical diagram prepared by the Council of our Institution in May, 1888, it will far exceed six million tons. The value insured in the same area by local mutual and other insurance bodies, having under their orders an excellent staff of surveyors, amounts to more than twelve million pounds sterling per annum. May we not therefore put the question—Are there not here the elements of a successful North-East Coast Shipping Registry?

DISCUSSION.

The PRESIDENT said, Mr. Macarthy, one of the Associates of the Institution, had brought before them a very important subject. They were extremely obliged to him for doing so. They had often sought the assistance, or rather the interest, of their outside friends, especially of their Associates, in giving them papers, and here Mr. Macarthy had given them one of an important practical character. He raised the question—"Is a North-East Coast Register of Shipping desirable or necessary?" It was not for him (the President) at this period of the discussion to guide their thoughts on a subject of this nature. Largely, it was a question for shipowners. They had some shipowners there that night, as well as practical shipbuilders and engineers, and they had, besides, a gentleman whom he was extremely pleased to see—his friend Mr. Martell, of Lloyd's, London

—and he trusted he would favour them with his views on this subject at a fitting part of the discussion. He might say that it would not be in their power to close the discussion that night. It was one of the bye-laws of this Institution that a discussion must stand adjourned till the following meeting. Therefore, they would be very glad to hear, till ten o'clock, the views of members and other gentlemen present, and he hoped that whatever they might feel, however warmly they might feel it, they would discuss this very important and knotty question with candour, gentlemanliness, and good feeling. He begged to call upon Mr. Wigham Richardson to open the discussion.

Mr. Wigham Richardson said that, as their President had pointed out, the important part of the paper was in the last paragraph, viz., whether it was possible to establish an independent registry for the classification of ships? Their President had also remarked that it was mainly a question for shipowners. Speaking as a shipbuilder this remark commended itself to his humble view, whatever the shipowners might choose to do with their property, it was for them to say, and not for the contractors who built them. But whatever registry, whatever classification the owners assigned to their ships, they as shipbuilders would be glad to second their efforts, and do everything they could to try and keep up the quality of the ships. There was one point that it seemed to him had been missed in the valuable work which Mr. Macarthy had alluded to—the *Annals of Lloyd's Register*. The title was a modest one—it spoke merely of being the *Annals of Lloyd's Register*. He had thought sometimes that the compilers of that work might have gone further and given them some history of what he might call "Inspection." Shipowners had been anxious not only to have their ships classed and a good character given to them, but they had also been anxious to clear themselves of responsibility. In the same way, the shipbuilders had been anxious to clear themselves of responsibility. They wished to be able to say—having built our ships to the owners' direction and to the best of our ability, we have no further responsibility in the matter. This feeling of getting rid of responsibility seemed to be taking wider and wider steps every year. They had always seen it grow more active when there was some special legislation, such as the Plimsoll legislation, which has resulted, as is well known, in a great extension of protection and indemnity associations. When there was legislation a few years ago throwing responsibility on employers, straightway there sprang up employers' liability associations, which the employers joined simply to get rid of their responsibility. In the same way he might instance the inspection of boilers paid for by owners

of boilers to get rid of responsibility. Whether this after all led to the higher walks of shipbuilding or shipowning perhaps it was not necessary to discuss. It was evident that that society would have the best chance of support which had the highest prestige, and which kept up the quality of the vessel which it admitted to its registry. It would also be strengthened by widening in every possible way the basis on which it rested. He thought for his own part, that the difficulty of starting a new registry would be very great indeed. He did not think it would be wise for Mr. Macarthy or any other gentleman to contemplate such a thing. They should not lose sight of the fact that they had now in existence two societies—Lloyd's Society and Bureau Veritas Society—with a long and honourable history, and governed by bodies certainly anxious to meet the wishes of everyone connected with them, and anxious to do right. No doubt there was a great deal of conservatism connected with them—with both of the societies—perhaps as much with their friends in London as anywhere else, they were a very conservative body; but he was sure Lloyd's would be glad to have any support or expression of opinion that would help them to move forward in the path of progress. If he had spoken of the two objects of classification—the one to give a character to the ship and the other to get rid of responsibility, he might also say, that in his opinion, and he spoke of Lloyd's and also Veritas, that they had two separate functions, and it was in this, the dividing of these two functions, that the greatest mistake had been made. One function of Lloyd's Committee in London was to assign the character of the ship and to see to the general administration of the society, the other was the framing of the rules on which those ships would be built, and he thought in the latter part they had gone very far wrong. They had arrived at their present rules by a system of adoption from ships actually built. It had always seemed to him that if Lloyd's had called upon shipbuilders to frame rules for construction, in fact to take up their functions entirely they would have saved themselves much trouble and strengthened the society. He did not think that Lloyd's imagined that the shipbuilders would have done anything to lessen the quality of the ships and he was certain they were aware that diversities of opinion existed among shipbuilders as to how these rules could be framed; but this much seemed to him clear, that many questions which had since been arrived at in a roundabout way—the load-line for instance—would never have got into the muddle it did had the framing of the rules been left to the shipbuilders. The deplorable agitation, too, of Mr. Plimsoll would have been avoided if vessels had been treated in the way done by shipbuilders many years

before Lloyd's treated them. Both the late Mr. William Denny and Mr. Robert Duncan, of Glasgow, pointed out that they would never get any true basis of the scantlings of ships unless they based them upon a part of the ship that might be measured up to the water-line, and if they had done that, it would have solved the load-line many years ago and saved much heartburning. The Bureau Veritas had been mentioned with praise by Mr. Macarthy, and he should like to be allowed to say something himself in praise of it. They, shipbuilders in England, had received a large number of foreign orders for building ships for foreign shipowners. It was a very valuable part of their business, carried on with satisfaction to both parties; and some shipowners abroad seemed to have greater confidence in the International Bureau Veritas than in the English classification. Personally, he thought they might have equal confidence in Lloyd's, but as a matter of fact some of their foreign friends did not think so. Veritas, he had heard it said, when recently abroad, always based its rules on scientific principles, and were not swayed by outside influences and the fear of competition, as some other societies had been. At any rate, some foreign shipowners had greater confidence in the Veritas, and when shipbuilders derived such benefits from abroad in the way of orders, there was a good reason for giving all the assistance in their power. He understood that the Veritas considered it did not get fairly treated by the English Government, and that English builders should step forward and assist it, if they had any influence, to see that fairplay was done. One complaint Mr. Macarthy made was really a complaint not in any way against the character of Lloyd's Registry, but against centralisation, and that was a very serious complaint. If the committee who had to do with the construction of the ships were situated amongst themselves instead of in London, and were in touch with the people building the ships, it would be a very great improvement. He (Mr. Richardson) enquired of one of their staff, before he came away, if he could give him any suggestions? He said, "If you can do anything to stop delays it would be a great thing." It came about in this way. If they were proposing anything different from the rules, if they would just take an express train up to London, and go and see the surveyors, and talk it over with them, they would probably have the thing settled satisfactorily in a very short time; but it was not always easy to take an express up to London, or feasible to do it, and he remarked that going through the regular mill, as it were, took time——

Mr. Boyd—I rise to order. No one wishes to interrupt Mr. Richardson, but I cannot help putting it to him whether he has not exceeded the ten minutes' rule?

Mr. RICHARDSON said he always felt uneasy lest his remarks should be too long, but could not see any clock. He would be glad if some other gentleman would go into more detail on a subject with which they are better acquainted.

The PRESIDENT—Mr. Richardson may extend his remarks upon examination in the proof.

[Mr. Richardson has written to say that he meant in his interrupted remarks to allude to the large income of Lloyd's, which is understood to be mainly derived from the fees paid by shipbuilders, and that this constitutes a claim that the society should meet the views of its largest financial supporters, and place the centres of the technical work and of surveying close to and in touch with the building yards and engine works. There was the further question of taxation and representation (which had been well treated by others), but in no case did he think that the mere amount of underwriting had much to do with what he urged and begged to repeat, viz., that the framing of the rules for building ships was a function that could best be exercised by the naval architect, that is by him whose daily work is to design, and that it should neither be left to underwriters, nor to shipowners, nor to merchants, nor even to surveyors, *as surveyors*, although many of the staff at Lloyd's might be fully competent to handle the question. Also that it is due to the shipbuilders, and only consonant with the spirit of the age, to give them every despatch in considering and passing plans, and this can only be done by delegating the fullest powers to a committee either of representatives or of surveyors who shall have their place of meeting close to the building establishments.]

Mr. ARTHUR COOTE said, he did not understand from the reading of the paper that there was any intention on the part of the writer to call in question the merits or demerits of the rules as to scantlings which had recently been issued by Lloyd's Classification Committee. Indeed, he gathered that he (Mr. Macarthy) did not attempt to deal with, or give any opinion upon Lloyd's rules, or those of the Bureau Veritas—both modified to suit the times. The question asked was—Would a North-East Coast Register of Shipping be beneficial to the district? and the chief cause of complaint against the existing state of affairs was, that Lloyd's Register is a big monopoly, and is moved too slowly. On these objections he had a few words to say. It was very generally admitted that a monarchical form of government—a one man rule—would be the best form of government, provided you could always get a perfect monarch or a perfect man. When, however, the impossibility of

attaining this was conceded, they did not thereupon split up the country into smaller parts, but they united the whole by electing from all parts direct representatives, and when these were assembled the monarchy was constituted; and as a constitutional monarchy they believed that this country was the best governed of any country in the world. In this district they had the North-Eastern Railway Company, which was a great monopoly, but it was largely admitted that it was very questionable if the people of this district would be better served were this monopoly seriously interfered with. At present it was fairly remunerative as an investment, and having on its Board a number of the best men from amongst them; these, aided by the pressure that public opinion was able to bring to bear on its organisation, resulted in their having a system that was well managed, and on the whole gave very general satisfaction. Well-established governments, as also powerful societies and public companies, had vested in them great responsibilities, and by necessity therefore it followed that they were slow to move; but in this age of extended and extending intelligence, the tendency was to move too fast rather than not fast enough, and it would be in his opinion a distinct disadvantage were they to insist on their Government or their societies or their public companies that their fixed or leading principle should be to move quickly. Lloyd's Society was undoubtedly a most powerful institution. He believed it to be a power for much good. That they, who represented so largely the shipbuilding and engineering industry, were not more largely directly represented on their committee was to a very great extent their own fault, and he would recommend that this fault be remedied in any possible way, rather than that any attempt be made to establish a North-East Coast Registry of their own.

Mr. John Price really thought they had not got on to the right line in the discussion. He did intend to have sat sometime longer, but he felt that the paper required criticism, and exordiums upon general principles did not quite meet the case, and he (Mr. Price) was not disposed to let Mr. Macarthy off so easily. The writer of the paper told them to begin with, that he had neither the knowledge technically nor scientifically to express an opinion upon this important subject, and yet he told them in almost the last line, that "had a committee been sitting in Newcastle this matter," which was the crux of the whole question, "would have been settled in twenty-four hours." How did he know that? Well, he (Mr. Price) considered that this was an unfortunate kind of paper. He had had occasion to stand there some years ago and have it objected to him that a paper he

produced was not like previous papers, by a very old hand in the Mechanical Engineers' Institution, and he felt very much the weight of it; but it was, however, quite pertinent to the discussion of steel as a material for shipbuilding. He felt, therefore, some sympathy with Mr. Macarthy, when he said this was the first paper he ever knew that put the whole subject to the meeting for discussion for his special information and the class he represented. Now, they were not public advisers on questions of this kind. At the same time, he (Mr. Price) thought it might be considered ill-manners to refuse to deal with such a subject when brought before them in this way, although the only question submitted to public discourse was one on which the writer gave them no opinion whatever of his own upon it, and told them at the outset that he was unqualified to do so. It was quite an original idea altogether; but this might prove a very interesting and very important discussion from two different aspects. If they were to go back historically to their varied experiences it would be more lively than instructive; but if they reviewed the position in which the shipowning and shipbuilding community stood to each other at the present day it would be found to be unique and singular in very many important respects. He would now deal with the question for a moment as to whether a registry was practicable, and he began by saying it was not, and lay down two principles which governed the demands for justice in times past. There had always been some great violation of a principle or some great alleged want in their effective and intelligent administration. If they went back twenty-five years the iron shipbuilding was in its infancy. At Liverpool they rose against the principle on which Lloyd's (?) based the scantling of iron vessels. They dealt with a ship as a box instead of as a girder of any length, breadth, depth, or any variation of these dimensions. Well, this was fairly assailable ground. On the other hand, they had to say "Your administration is faulty; you deal out a class or character that is no indication of the value of a vessel." There was on this point a very long and severe contention—he meant a conflict of opinion, perfectly intelligible, with no personality involved—and they knew that as the result either of that early contest or growth of intelligence, and the widening of ideas in their relation to the whole question, both these principles were intelligently considered and largely dealt with. The basis upon which a ship was built to-day was largely that of a girder, at the same time, it was dealt with as a vessel whose form was of very material consequence as an element in determining her strength as a girder, and in relation to the element in which she

had to swim. And then in regard to the classification of the vessel's character and the general administration of Lloyd's: they knew they could not get a more perfect expression of unity than 100. He must tell them that all through the contentious period the people who dealt with these matters felt this difficulty, and he might say now as a matter of fact, that those who had given most consideration to the subject were convinced that the unity was the proper form in which to express the durability of a ship, and the opponents of Lloyd's had their feet cut from them by this action of Lloyd's. The resolution to adopt "100" as the symbol for indicating the value of the iron and steel ships was a *coup* and the very finest stroke delivered to their opponents. At the same time, it expressed, what everyone then connected with shipbuilding and shipowning was compelled to admit, a form of unity by a symbol which could not very well be improved upon. Now, to-day what had they to complain of in Lloyd's? He (Mr. Price) could not agree with Mr. Macarthy in his example of the petroleum ship. He could not have given them a more unfortunate illustration in support of his contention that Lloyd's were slow to move, for he must say he was astonished with the readiness, the instantaneousness with which their proposals were accepted by Lloyd's. He (Mr. Price) did not think he ever passed a ship through with more complete satisfaction as to the pleasantness of intercourse and rapidity of decision come to. Now, with regard to the apocryphal ship, for he had heard of it for the last twenty-five years, being riddled with rivet holes, Lloyd's never asked for more than one hole in one plate, and when they considered that there were more than 300 holes in one plate for securing it in its place, what complaint could owners have to one hole more in an old vessel to ascertain the thickness? He would only recall to mind in passing, shipowners depended upon shipbuilders largely for their advice, and were led by them when they took an intelligent view of any constructive matter; but here they were left to guess as to what was the complaint shipowners had against Lloyd's. They talked about a monopoly—they could not always do without them, and Mr. Milburn, as a Tyne representative on Lloyd's Committee, did his best to make use of that monopoly in London in the interest of shipowners, and there was nothing less assailable than that aspect of the question. There was one thing be would say of Lloyd's. They knew what constituted the basis on which they rested for support, viz.:—the intelligent and willing support of what he should call "their customers!" When they began the Liverpool Registry, Lloyd's Committee and their friends had not recognised this—they thought their inherent strength

and their prestige sufficient to support them—but he (Mr. Price) said advisedly, and his friend Mr. Martell would not object to it, the Liverpool Committee and staff made them feel they rested upon a more popular support which was at last frankly admitted, and now they wanted to have this basis a little more widely extended. Let it not be said that ships were built by shipowners and underwriters, and merchants, who know nothing of the principles of construction, and those who only know how to construct the vessel were excluded. The shipbuilders and the engineer with their extended knowledge and wide experience would be of essential use and need to the committee, now that engineers and shipbuilders were all scientists from youth, and the sailing vessel and steamer had invaded their province. What they wanted was to have Lloyd's wisely infused with that element, by which the construction of ships was alone understood, and he thought they would prevent the elements from clashing. They would, that was to say, exclude errors from the construction of a ship and bad administration in the conduct of the society.

Mr. B. MARTELL (of Lloyd's), at the invitation of the President, next addressed the Institution. He thanked the President for allowing him to make a few remarks on that occasion, seeing he was not a member of the Institution. Although he had not been present before when papers were read and discussed, he had read with the greatest interest and benefit the addresses of the President and his predecessors in the chair. The papers, too, which had been read by some of the members, had been to him replete with interest and benefit, and it was a great pleasure now to be able to offer his thanks to the Institution for the very excellent papers produced. The opinion he thus expressed was endorsed by the members of that older institution, the Institution of Naval Architects, of which many present were members. Having said so much he would now apply himself to this paper. He should not take up their time by any remarks upon the main body of the paper, because, he might say, it was ancient history, which most of them had read before. He quite saw where Mr. Macarthy had deviated from the work out of which he had got his information, and regretted very much if he were traducing him when he said that there was in it an animus depreciating the Society of Lloyd's Institute in comparison with other register societies he referred to. However, that might be let pass, as it did not matter much. He only regretted that there was not more in this paper, similar to those he had referred to and read by many members of this Institution, where the purport of it could be discussed from a

scientific point of view. Of course there was nothing in the main body of the paper to discuss; but seeing that, he supposed that they must be thankful for small mercies, as although there was nothing to discuss, he was only glad to think that it had afforded him the opportunity of coming there and availing himself of their kindness to say a few words in order to rectify, if possible, the misapprehensions, and he might go to the extent of saying misrepresentations, made in this paper, and on other occasions in this locality, affecting the institution he had the honour to serve. In the first place——

Mr. EDWARD ECCLES—Excuse me interrupting, but it is scarcely right of Mr. Martell interposing at this point of the discussion. It would be fairer, after this discussion was concluded, to allow Mr. Martell to reply. I do not think it is right to allow Mr. Martell to interfere at this point.

The PRESIDENT—We are under an obligation to Mr. Martell for having come at all. He must leave this evening, and I asked him to say a few words, and we shall be very glad to hear what he has to say.

Mr. MARTELL said he regretted very much to have to rise at an improper time. He felt the inconvenience of it, for it would be better for him to sit and listen to what every one had to say, and then make his remarks, but it was impossible for the time at his disposal. In the first place, Mr. Macarthy said he distrusted monopolies. Of course, they all distrusted monopolies, and liked fair competition; but what was material was to get the proper meaning of the word. He did not think it applied to Lloyd's Register. It was a committee composed of various representatives from all the great ports of the country. For the Tyne alone they had three representatives, representing the shipowning interest in the district, one of whom (Mr. J. Milburn) he had great pleasure in seeing present; and very good representatives he could tell them they were. Whether the number was sufficient he was not competent to say, that was not for him to deal with; but a representative committee, composed of members from the various ports, and brought into connection with Lloyd's Register, was not a monopoly. How could it be when it had a competitive society—the Bureau Veritas—having all these ships classed in their books, as was told by Mr. Macarthy; and shipowners were as free to go to it as to Lloyd's Register? How could it be a monopoly when freedom was left to the shipowners to class their ships where they liked, and where they were fairly represented in Lloyd's Register? This merely by the way. Now, as to what Mr. Macarthy

said, and they could think what they liked about it, he (Mr. Martell) surmised there was something, he could not tell what, behind the scenes. Take, for instance, the petroleum tank question with which Lloyd's dealt. Now, he should like to say, Mr. Macarthy, perhaps, did not know it, that in 1872 Lloyd's Register had placed before them drawings for two or three ships of about 3,000 tons to carry oil in bulk, and those were very magnificent ships. He (Mr. Martell) was consulted first, knowing the chairman of the company especially, and likewise the builders; and those ships were built as well as any ship could possibly be built by Messrs. Palmer & Co., and had trade not altered, so that the owners thought it better to put them in some other trade, it would have been found that no steamers had been constructed to carry out the work intended more efficiently than those ships. He had taken a great personal interest in this matter from the very first. Talk about steamers carrying petroleum in bulk! He thought he had a witness present he could call on, a gentleman—he did not know if they knew him—Mr. Marvin, a great authority on the petroleum business. He (Mr. Martell) took such an interest that he collected all the information he could bearing upon this great question—the carrying of petroleum in bulk rather than in casks—and embodied it in a paper, and read it at the Institution of Naval Architects at Liverpool. He felt it a very high compliment when on that occasion Mr. Marvin expressed his thanks on his taking upon himself to bring this great question before the public. He had expressed himself to the effect that he would do all he could to introduce to shipowners the carrying of petroleum in bulk, and do what he could as professional adviser of Lloyd's Committee; in short, taking the matter up, as they did immediately, he could not see how they could call it "obstructiveness," holding them up to reproach and almost ridicule in regard to this petroleum-carrying question. He (Mr. Martell) objected to such misrepresentations being put forward, and he regretted very much to say it was not the first, second, or third time in this locality where these misrepresentations had been put forward, and he thought they would agree with him that he must really express the opinion he could not help thinking, after such persistency—making these misleading statements, time after time, in this locality—there must be some sinister influence at hand that gave rise to this, and he hoped if it was so the explanation he made of the interest Lloyd's Register had taken in this question, would cause the persistent misrepresentation of Lloyd's action with reference to these ships to cease. Now, with regard to the well-deck steamers. What was the condition of the loading of steamers before

Lloyd's Register took the question up? How were they treated by the Government? How coerced every way, and prevented sailing their ships properly? Not until Lloyd's took the question up, and put forward the load-line tables, framed on a scientific basis——

The PRESIDENT—I don't want to stop Mr. Martell if it is your pleasure that he should go on.

Mr. PRICE—I should move that Mr. Martell be allowed to finish his observations.

The PRESIDENT—I take it to be your pleasure Mr. Martell should be allowed to proceed.

Mr. MARTELL (continuing) said he was grateful to the President and Mr. Price for registering it, for he looked at Lloyd's Registry Society as being on its defence before the public. If they would allow him to say a few words in explanation he should be exceedingly pleased. In regard to this load-line question, it was not until Lloyd's and those who understood the question thoroughly took it up that anything was done. He could understand Mr. Macarthy less when he said he did not understand it; but if he did not understand it why put forward statements like this? If Mr. Macarthy would take the trouble of coming to his office he should be delighted to show him the real honest work which had to be done before those things were accomplished. They were no child's play. He (Mr. Macarthy) seemed to think it a matter of the greatest simplicity dealing with this question of loading; he could, however, assure him it was not such a simple question, but a very complex question, indeed one of the most difficult and complex questions scientific men had to deal with, and with the best scientific and technical knowledge to guide them. Shipowners were appealed to, and helped greatly in bringing this question to maturity. He should like to ask Mr. Macarthy how much information he gave in bringing this to maturity? Now that they had succeeded in having a load-line placed upon the ship, and relieved them from all responsibility, and from coercion of any kind, for a shipowner to stand up and reproach Lloyd's Register, he should say to him like Cæsar to Brutus—*Et tu, Brute!* Now, here was another case—he wished he had a hundred cases of this kind to reply to, strong cases of this kind put before the public in the manner this was done. He (Mr. Martell) could congratulate Mr Macarthy on this one point, and it was the only thing he could congratulate him upon in this paper—he was fortunate enough to get the Council of this great and scientific Institution to allow him an opportunity of coming forward there and reading a paper of this kind. Now, Mr. Macarthy related about a steamer—it would have been better

and more honest if he had told them it was a steamer of his own—which, he might say, being nearly thirty years old, required very careful examination. This ship required to be detained from five to six weeks, for work that might have been done in seven days. Possibly this might be so, or even an hour if a man could look through the plates and see the condition inside. He was sorry to say it, but he must make use of strong words: it was a garbled, and not a truthful account.

Mr. MACARTHY (rising)—I appeal to the chairman.

Mr. MARTELL said he did not come there without making most careful enquiries. He was not accustomed to make statements before the public he was not prepared to defend and expound. It was stated there that the surveyor told the owner of the ship it would take about five or six weeks to be done. He was quite prepared to prove that there was no surveyor in their society ever said anything of the kind.

Mr. PRICE—I would suggest, out of respect for our usual decorum, that Mr. Martell should not go through the details of the case, but state generally whether he concurs with it or not.

Mr. NICHOL—I think the arguments might be put forward in a straightforward manner, without trying to make ridiculous the reader of the paper.

Mr. MARTELL—Might he be allowed to say that in the paper Lloyd's Society was held up to ridicule and contempt. They must allow a little freedom in his endeavouring to explain their conduct and that of their servants in the matter. That account he did not agree with in any shape or form. If he might be induced to put the statement before the public, he should put it in a very different manner from that in the paper. He (Mr. Macarthy) professed to call the attention of the public to the question whether it would be advisable to found a register of shipping in this district. As had been properly said, this was not his business—it was a shipowners' question, and he might be allowed to say further that the main argument, the only argument, for doing this was that the value of the assurance here amounted to twelve millions pounds sterling, and it was a very fair argument for the advice given in establishing the proposition put forward. He might say that when the last statistics were taken, two or three years ago, and in making the statement he thought every one knowing him would know that he would be the last to disparage the North-East Coast—he had lived there and knew the energy of the people, and that they were the most enterprising and successful shipowners in the world, and what he was going to say was not in any way to disparage the port; but he wanted to show them that the value of twelve millions

sterling was a mere flea-bite!—when these statistics were taken a few years ago the amount of insurance effected in London was £600,000,000!

Mr. PRICE—In the year?

Mr. MARTELL—At one time; the value of insurance.

Mr. PRICE—Policies running?

Mr. MARTELL—£600,000,000 in policies running; Liverpool, £180,000,000; Glasgow, £50,000,000. On the North-East Coast it amounted to £12,000,000. Mr. Macarthy was quite right in that.

Mr. PRICE—Would the North-East Coast not refer to hulls alone, and London to hulls and cargoes?

Mr. MILBURN—The figures were really £16,000,000, and referred to hulls and everything.

Mr. MARTELL (continuing) said, if the Liverpool Registry, based on broad principles and conducted as it was by men of the highest intelligence, and having in the locality insurance to the extent of twelve times as much as in this locality—£180,000,000—if after running some years they found it was wise to co-operate with Lloyd's Registry Society and give up their very book, he thought that spoke a great deal as to what would be the probable success of a separate registry in this locality. However, he expressed himself rather freely, and if he had said anything to offend Mr. Macarthy's feelings, he (Mr. Martell) must apologise; but when he saw here that the head and body of this paper was formed by information actually supplied by Lloyd's Registry, and that that was supplied for the purpose of appending this very stinging tail, they would forgive him if he felt that it was rather cruel upon Lloyd's. They little thought in furnishing that information it was going to be used for such a purpose, as the weapon to strike themselves down. It reminded him of the words of the poet:—

> "Lo the struck eagle stretched upon the plain,
> No more thro' rolling clouds to soar again,
> Viewed his own feather on the fatal dart,
> That winged the shaft that quivered in his heart:
> Keen were his pangs, but keener far to feel,
> He nursed the pinion that impelled the steel;
> While the same plumage that had warmed his nest,
> Drank the last life-drops of his bleeding breast."

He (Mr. Martell) could only conclude by merely saying, in his opinion personally, he thought so long as Lloyd's Registry Society was conducted in the manner it was, with that single-mindedness and determination to safeguard all the interests entrusted to it; and its officers were men of integrity and men who understood their business; and that they were, he was sure, he could appeal to shipowners and shipbuilders present, and in expressing an opinion they would not, as Mr. Macarthy, "damn them

with faint praise"—he had confidence that so long as Lloyd's Society was conducted in that way, he did not think they need fear the advocacy put forward in this paper—to form a competitive registry in this locality.

Mr. HENRY F. SWAN said he had not intended to take any part in this discussion, but as tank steamers had come rather prominently into it he desired to say a few words. From a remark made by Mr. Martell he feared the latter had an impression with regard to the expression Mr. Macarthy used about tank steamers, seeing how largely they were identified with them, that they might, perhaps, have had something to do in putting that forward.

Mr. MARTELL—May I say I neither said so nor suggested anything that Mr. Swan could take to himself.

Mr. SWAN (continuing) said he did not know Mr. Macarthy was going to read the paper; he had had no conversation with him on the subject, and therefore he did not know what he had in his mind regarding tank steamers. Being now on his legs he should only say this, that towards the end of 1885 he had occasion to see Mr. Martell on the subject of building a tank steamer, and strongly advocated the carrying of the oil to the shell of the ship. At that time Mr. Martell had a very strong objection to it; but when he read his paper in Liverpool in the following year his views, he thought, had undergone considerable modification, and Mr. Martell took a very different view from what he had previously done. That might possibly account for what Mr. Price said, viz., that on submitting his first section he had no difficulty in getting it passed quickly through. In the meantime the subject had been very carefully considered, and Lloyd's, he must say, had very intelligently examined the question, and given it more thought than, perhaps, they had done before. He had many interviews with Mr. Martell on the subject, and perhaps he did a little to clear away the doubts which existed in his mind previously. On the subject of Lloyd's Register generally there was no institution could be free from faults; but, on the whole, he thought they had every reason to be proud of Lloyd's, and the way in which they did their work. It was an extremely difficult position they occupied, and considering the variety of interests they had to satisfy it had often been a wonder to him how the numerous sections that were sent up could be so quickly returned approved or otherwise. But still there was a feeling that in such a large interest as shipowning, shipbuilders should be represented so as to supply the technical information they got day by day in their usual avocation, and thereby give great assistance to shipowners; and he was sure the technical staff of Lloyd's would be glad to welcome an addition

to the committee in that shape. As he had said there had been faults, and he thought one of the greatest grievances they had had in recent times with Lloyd's had been where a section having been passed to-day, in another submitted a month afterwards for a similar ship considerable additions had been made. However, the issue of new rules had passed them out of this uncertain stage, and there would be no further trouble in that respect, and if, as he believed, the agitation going on for a little better representation from the technical side were successful all would work harmoniously, and he did not think there was any need for further competition in registries beyond what there was at present. The Bureau Veritas no doubt occupied a very important position, and it gave great assistance in dealing with technical questions, and their registry was growing a very important competitor, quite sufficient in his opinion to do away with the word "monopoly," and he thought in the future they would not have much to complain of, but on the contrary to be satisfied with the state of things as they existed.

The PRESIDENT said the technical side of the question had been talked out. He would be glad to hear some of their shipowning friends.

Mr. J. D. MILBURN, shipowner and member of Lloyd's Committee, said, he need not enter into a defence of Mr. Martell. Mr. Martell had done that for himself gamely. In fact he had soared far above the clouds, after the example of that noble bird the eagle, to which he had alluded in poetic language. The insurance figures were larger than those given by Mr. Macarthy for this district. He had occasion to get them for Lloyd's Committee when it was considering the desirability of increasing the representation of Glasgow. The figures were £16,000,000, including insurance upon cargoes, freights, and hulls—a mere drop in the ocean considering the magnitude of metropolitan insurance. Looking at the question: "Shall we have a register on the North-East Coast?" he had to ask: "Can we?" Lloyd's was largely composed of underwriters and merchants in London, Liverpool, and Glasgow. If they had an association of their own would not these gentlemen suspect them of giving themselves better marks than they deserved? Such a registry would have no confidence amongst those who looked upon registry as an impartial survey of condition and fitness, and therefore would fail. So much confidence was vested in Lloyd's that the rates of insurance had decreased, especially upon cargoes, and Lloyd's classification was sufficient to allow independent and particular surveys to be dispensed with, but these would certainly be demanded by the metropolitan underwriters before agreeing to effect insurances if

they went in for a local registry the members of which being almost exclusively shipowners. There was another question he would like to speak upon, viz., competition in registry. He deprecated competition in the registration of ships. He thought such competition productive of bad material and bad workmanship, a source of public danger, and a direct cause of loss of life and property at sea. He knew he was speaking in the presence of prominent gentlemen connected with the late Liverpool association and also in presence of Lloyd's surveyors, but it was his opinion that competition had at one time raged to such a height between these two societies that ships of a very inferior character were turned off the stocks. He knew of a brand new vessel which put into a port on her first voyage weeping at the butts, and another whose deck was inherently weak and had to be strengthened. He did not think they ever had had such seaworthy ships as they had now. He thought their type and character better than they had ever been, and he did not think they needed any other registry here. If they thought there was anything wrong in the administration of Lloyd's why not turn out their representatives and put in better ones? He (Mr. Milburn) however felt if he had got a good case to bring before the committee of Lloyd's based upon common sense and justice, merchants and shipowners were sufficiently strong in the committee to carry it against any prejudice or purely underwriting interests. Shipowners were getting gradually stronger in the committee. Witness the recent return of £6,000 in fees. They wanted £10,000 off and would have the balance next year. Lloyd's was not a money making concern. Having once got a pension fund they would not allow the committee to absorb capital beyond what was necessary to secure effective administration or for increasing the utility of the association. They were all obliged to Mr. Macarthy for bringing forward this paper. He felt that Lloyd's Register could bear full enquiry, and rather courted it than otherwise, for it brought out the facts. Mr. Macarthy called it a "one man affair." If he had heard a certain discussion between Mr. Martell and Mr. William Gray concerning the well-deck steamers before the committee, he would have called it at least a "two men affair." Flint and steel were as nothing when these two gentlemen came together on that vexed question, and it was a huge mistake to imagine that Lloyd's Committee did not act according to careful discussions and deliberations in committee. He felt that there were many gentlemen wishing to make remarks upon this interesting question and would not occupy more of their time, and he thanked the President kindly for giving him the opportunity of saying a few words on the subject.

Mr. A. SCHOLEFIELD, shipowner, said he should like to pour a little oil on the troubled waters, for he thought Mr. Macarthy was rather misjudged by Mr. Martell. Mr. Macarthy, he ventured to say, did not wish it to be taken in the serious line Mr. Martell had taken it, and he did think an Institution like this was at liberty to discuss any question they thought fit; and if they desired to discuss there whether they should have a North-East Coast Registry of Shipping, or anything else, it seemed to him that such a question was a proper one to discuss calmly and quietly. If after such a debate as it would receive, and after the careful analysis it would encounter by the members, it could not bear that criticism and analysis, it would be dropped; but if it would bear them, depend upon it they would have the support not only of this Institution but of others also. He did not want to justify, and he was sure Mr. Macarthy did not want to justify, any errors he had made in his paper. They were all human, all apt to err. Amongst the multifarious duties Mr. Macarthy had to fulfil, he might by inadvertence have stated things not absolutely accurate; but he (Mr. Scholefield) was certain Mr. Macarthy never deliberately intended to make any erroneous charges such as Mr. Martell had taken so seriously. Coming to Mr. Macarthy's paper, it was certainly to be regretted that he had not more elaborated the reasons for this North-East Coast Registry. In 1883 this subject was taken up very fully by their friend Mr. Laws. Mr. Laws then held that the mutual associations had the power amongst themselves of forming a registry, and he went a good way in getting information from all parts of the country. The mutual clubs had then insured property to the value of something like twenty million pounds, and Mr. Laws maintained they were in a position to give a proper classification for vessels—they had all the surveyors and apparatus for carrying out a registry for shipping. This question was thoroughly gone into at the time, but dropped. If in 1883, with twenty millions of capital, the clubs could not do it, how could they now when it had dwindled to one-fifth of the amount? Mr. Laws confirmed the view that as far as the clubs were concerned it could not be taken up, and he (Mr. Scholefield) agreed with Mr. Milburn that the whole scheme of a North-East Coast Registry of Shipping was impracticable. He would suggest that they should if possible get a branch of Lloyd's for the North-East Coast such as they had at Liverpool. If Lloyd's could see their way to do something of that kind it would meet most of the difficulties of the case.

The PRESIDENT closed the discussion for the evening, to be resumed at the next meeting in Sunderland. He moved a vote of thanks to Mr. Martell for coming there that night.

This concluded the business.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

SIXTH SESSION, 1889–90.

PROCEEDINGS.

SECOND GENERAL MEETING OF THE SESSION HELD IN THE LECTURE HALL OF THE SUBSCRIPTION LITERARY SOCIETY, FAWCETT STREET, SUNDERLAND, ON FRIDAY EVENING, NOVEMBER 8TH, 1889.

F. C. MARSHALL, ESQ., PRESIDENT IN THE CHAIR.

THE SECRETARY read the minutes of the Annual Meeting, held in Newcastle-upon-Tyne on October 21st, which were approved by the members present and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. J. C. Stirzaker and R. L. Weighton to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Brown, Robson, Belle Vue Terrace, Tyne Dock.
Bonneyman, James Smith, 8, James Mather Terrace, South Shields.
Edwards, James Henry, Byethorn, Corbridge.
Evans, William, 2, Salisbury Street, Sunderland.
Hogg, James, 14, Hylton Terrace, Upper Coach Lane, North Shields.
Hills, Charles Henry, Anglesey Copper Works, Walker-on-Tyne.
Ray, Arthur, c/o Thomas Ray, Forgeman, Sunderland.
Rooke, Charles Bowden, Jun., St. Paul's Road, West Hartlepool.
Stoldtz, Heinrich, c/o Messrs. Cifuentes, Stoldtz y Co., Gijon, Spain.
Weir, William, c/o Messrs. Wigham Richardson & Co., Low Walker.

ASSOCIATE.

Cohan, Edward Asher, 2, Rumford Place, Liverpool.

GRADUATES' MEETINGS.

The PRESIDENT said he wished to take the opportunity of reporting on one of the subjects brought forward during the remarks made at their last meeting with regard to the Graduate Section. As a previous general appeal to the Graduates was not very satisfactorily responded to, he took the liberty of writing personally to each, inviting them to meet one of the members of the Council and himself at the rooms of the Institution, to ascertain their views with regard to the formation of this section, and also to make their personal acquaintance. He was very glad to say that sixteen of the Graduates came together, and he must say a very intelligent, fine lot of young men they were; they entered most heartily into the project and forthwith proceeded to elect a committee; and after a few remarks from one of the members of the Council, who afterwards retired, they were left to carry on their own business. He might say they had constituted themselves, as the Council desired, into a Graduate Section of the Institution, for the purpose of reading and discussing papers amongst themselves, and they certainly looked, from the resolutions passed at a subsequent meeting, "like business." He hoped there was a good and great future before this section of the Institution, and that they would have these young men growing up to take their places as they fell one by one into "the great majority."

The discussion on Mr. G. E. Macarthy's paper, entitled "Notes on the Surveying and Classification of Shipping," was resumed; after which Mr. J. C. SPENCE read a paper on "The Strength of Boilers."

NOTES ON THE SURVEYING AND CLASSIFICATION OF SHIPPING.

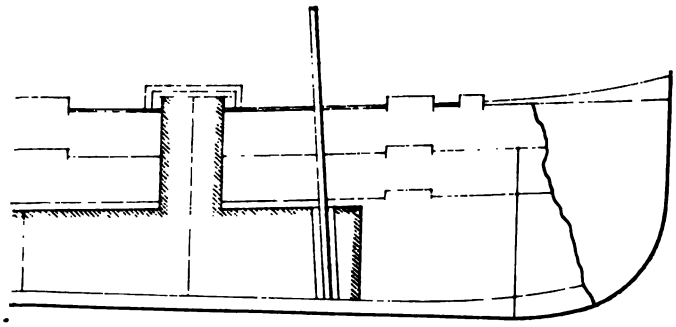
ADJOURNED DISCUSSION.

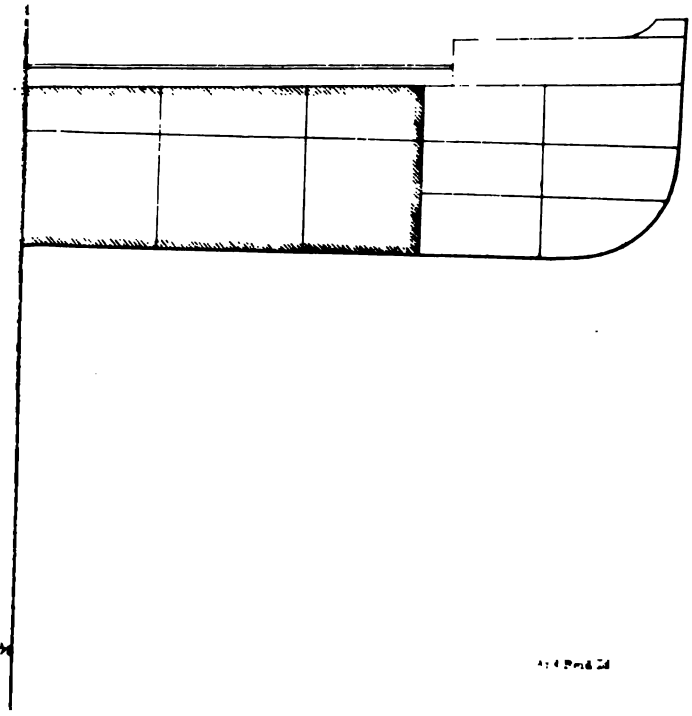
The PRESIDENT said their first business was the adjourned discussion on Mr. Macarthy's paper, entitled "Notes on the Surveying and Classification of Shipping," and he need scarcely remind them that they had a very lively and interesting discussion at their last meeting on this subject, and he had no doubt they would have an equally interesting discussion that night. He hoped that no member present would feel that he was under any restraint with regard to this discussion. They were most anxious to hear the views of all members on all the papers. It had become, sometimes from necessity, almost a habit with them to call upon gentlemen to speak on these discussions; it was not his intention to do so that night at all, he thought it was a reprehensible practice, it was much better that the discussion should be free and open to all, and no one should feel that he was under the necessity of waiting until the chairman called upon him. Mr. Macarthy's paper was one upon which there might be two opinions as to the propriety of its being read before this Institution, but he thought its object was a very general one, materially affecting their customers, the shipowners, and also, through them, he thought, it affected the shipbuilders and engineers. He (the President) could not say that he endorsed the view that this paper ought not to have been produced before the Institution. He thought the Committee did wisely in accepting a paper which would lead to the ventilation of a subject important to every one of them. He would just remind gentlemen that the avowed object of Mr. Macarthy's paper was to elicit the opinion of this Institution as to the practicability of establishing a North-East Coast Registry of Shipping, and, if practicable, whether such a registry would benefit the shipping interests of the district. Mr. Macarthy then, after mentioning some difficulties he had experienced with regard to inspections, went on to ask—were these difficulties not sufficient to justify, and were there not here the elements of a North-East Shipping Registry? Now, they had had a good many opinions very strongly expressed at the last meeting. He hoped each

speaker would have a due regard for the feelings of others, and not exceed the bounds of fair argument or of gentlemanly remark, the one towards the other. The discussion was now open to any member to proceed.

Mr. B. G. NICHOL said, he had not intended taking part in this discussion, but there were remarks made at the last meeting on which he should like to comment. This paper of Mr. Macarthy's raised a very important question, which at different times had been asked and almost as often answered in the affirmative: Was competition or rivalry beneficial? Now, in the case of institutions such as those which had come into this discussion, like Bureau Veritas and Lloyd's, it appeared to him of the highest importance that they should have competition, especially where they controlled to a large extent the shipbuilding and engineering industries. The tendency made directly for more efficient and more representative committees, as was so ably argued by several speakers at the last discussion, and also, to his mind equally important, tended to a higher and more able and more efficient staff, so that they might get rid for ever of those antiquated fossils who considered that a ship to go across the Atlantic should have a skin of not less than an inch thick and frames sixteen inches apart! Whether a North-East Coast Registry could be successfully launched was a question for the shipowner and the underwriter, with which, he thought, they were very well able to deal; but there was one speaker at the last meeting who he (Mr. Nichol) regretted very much indeed, took this paper as a direct attack upon the association with which he was identified, and adopted a strong partisan debating spirit in the discussion. He also regretted very much that Mr. Martell thought fit to pay a left-handed compliment to the President and Council of this Institution as well as to the reader of the paper, by complimenting Mr. Macarthy on having had such a poor paper read before an Institution like this. He (Mr. Nichol) fancied if Mr. Martell's remarks had been made in a less combative and less bellicose spirit they would have been much more appreciated. But passing by the charges of "misleading," "misrepresentation," and "sinister motive," he should like just to make one or two remarks upon that part of the subject referring to petroleum steamers. Well, he, in conjunction with Mr. Gravell, in 1886, read a paper on the transport of petroleum in bulk, that relating to the steamer being read by Mr. Gravell. Since that time they had taken a very lively interest in all pertaining to the carriage of oil in bulk, and he was exceedingly pleased to hear Mr. Martell say that as far back as 1872 he advocated

hy's paper.





the carriage of petroleum in bulk, and that plans of steamers had been passed at the time for that purpose. If he did not know better, if he had not enquired further, he should have gone away with the impression that Mr. Martell then advocated and approved the steamers they had carrying petroleum that day; but neither he nor Mr. Price told them that they were double skinned steamers, a type of which there was not one being now built. (See Plate I.*) He should have gone away with the impression that it was the steamer where the oil was carried out to the skin of the ship, and would have been misled. Mr. Swan in his remarks said that in 1885 Mr. Martell was distinctly opposed to the oil being next to the skin of the ship. In 1886 a steamer was so designed, but refused unless it had a double skin. He (Mr. Nichol) understood that the Bureau Veritas was willing to class it with a double shell, but preferred to have the oil carried out to the skin. He thought it was clearly established that Lloyd's Committee had stood very, very much in the way of the progress of the petroleum steamer to its present state of perfection. He could come to no other conclusion than that the alteration in Mr. Martell's opinions and the practice of Lloyd's Committee was due to the successful voyages of the S.S. "Gluckauf" in 1886, and to the fact that the Bureau Veritas had, during that year, classed a considerable number of vessels to be built on the same plan. He could only, in conclusion, congratulate Mr. Macarthy on having brought a paper before this Institution which had evoked such an amount of attention and interest.

Mr. J. GRAVELL (of Bureau Veritas) said that on first reading Mr. Macarthy's paper he thought there was nothing that he might have to comment upon, and therefore did not intend to take part in the discussion; but since the discussion took place he found that there might be one or two remarks made in reference to rival societies. Rival

* The following communication has been received from Mr. Nichol:—

November, 1889.

THE SECRETARY, N.E.C. INSTITUTION OF ENGINEERS AND SHIPBUILDERS, NEWCASTLE-ON-TYNE.

DEAR MR. DUCKITT,—I beg to enclose sections of the steamers referred to by Mr. Martell, in his remarks on Mr. Macarthy's paper, as having been passed by Lloyd's Committee in 1872, for the carriage of oil in bulk, and likewise of the S.S. "Gluckauf," to which I made reference, as having been passed by Bureau Veritas in 1885, and trust that you will kindly arrange for them to appear in our Transactions along with my remarks.

Yours faithfully,

B. G. NICHOL.

(For these Sections, see Plate I.– EDITOR.)

societies did not actually mean competitive societies. He thought if it was to be admitted that there was any rivalry between Lloyd's and Bureau Veritas it was a thoroughly healthy and necessary rivalry, inasmuch as it must tend to the benefit of both shipbuilder and shipowner, as well as to that of the societies. The Bureau Veritas might have benefited in many cases by Lloyd's experience, and there was no doubt Lloyd's had benefited by the Bureau Veritas' experiences. In Mr. Martell's remarks he found some statements made which were correct in substance but not in the actual fact. He said that as early as in 1872 they (Lloyd's) had plans put before them for vessels carrying oil in bulk. The plans of the same vessels were also submitted for the approval of the Bureau Veritas. Those vessels were good, well built, staunch, and strong, no doubt, but they had no proof of them having ever been efficient for carrying petroleum in bulk. Again, Mr. Martell said that he was the pioneer, and encouraged the carriage of oil in bulk, and that he did so through a paper he read at the meeting of the Institute of Naval Architects held in Liverpool in 1886. This was hardly correct, as he (Mr. Martell) did not explain the type of vessel of which he then approved. At the same time that he was encouraging shipowners to build steamers to carry oil in bulk he was stopping the construction of the type of vessel which was then being constructed, and had since invariably been constructed for the carriage of oil, viz., out to the skin. He (Mr. Martell) did not approve of that system, in proof of which the very vessels which he showed diagrams of, and which were submitted for approval to his committee, were being built under their inspection to class their highest class, but with the proviso that "the class did not extend to petroleum fittings." How could Mr. Martell explain his assertion that he encouraged shipowners to build these vessels when he had no confidence in them himself, as he was not prepared to class them out and out? How could a vessel be built specially for petroleum, and not classed to carry it, by the fact of the class not extending to the petroleum fittings? What had made Mr. Martell or his society alter these views? He wished to put forward to them the benefit of two societies and two opinions. There was not the slightest doubt that Mr. Martell did not approve of the single skin (the present construction), but insisted on a double skin. He (Mr. Gravell) differed from Mr. Martell, and advised his committee that the proposed plan of a single skin was actually the safest and most economical for the transport of oil, and therefore he maintained that the alteration in Mr. Martell's ideas was entirely due to

his committee, in accepting the classification of these vessels. Further, he thought that registry societies should be in a position to judge on new departures without first experimenting.

Mr. H. MACOLL said, Mr. Macarthy's very interesting paper covered such a large amount of time, ranging from before the ark until the present date, and even projecting somewhat into the future, that it was rather difficult to start making remarks, and more difficult still to know where to leave off. The gist of the paper, however, seemed to hinge on the question of the benefits or otherwise of the present system of classification. Now, so far as bulk oil steamers were concerned, it was within his knowledge during the last five years that Lloyd's would not class a steamer to carry petroleum in bulk, either with a double or single skin, and one reason given was, that vessels had been built some twelve years previously for the Continent which were not found to be suitable for carrying oil in bulk, even after every care had been exercised in the building of them. One of the vessels referred to was at the time alluded to lying at Antwerp, and a visit was made there to ascertain something as to the actual state of the matter, when it was found the whole concern resolved itself into this, that the municipality of Antwerp had prohibited the import of oil in bulk into the harbour. These vessels carried ordinary merchandise, and were found to make splendid grain carriers, but were lately found rather small for the transatlantic trade, and they did not carry petroleum simply because they did not get the chance, and certainly did not give grounds for any argument against other vessels being built for the oil trade.

There can be no doubt that registry associations were largely influenced, and he might say benefited, by their close and continuous communication with those engaged in the manufacture of ships and engines, and he did not believe the members of the Institution, however much they might be inclined to respect Lloyd's and other registry associations, would be at all inclined to concede the claims put forward at their last meeting for something like perfection, and also for accurate forecast of the future. It was quite true the chief surveyor to Lloyd's Registry read a paper on oil vessels; but how much had Lloyd's done to further this growing industry until others had led the way and made the matter an accomplished fact? All large similar institutions had a tendency to get into an established system, and did not take kindly to innovations in ordinary practice. In fact, when anything novel was proposed, the first thing the surveyor usually said was, Why don't you build the vessel according to the rules? However close to

perfection Lloyd's or any similar institution might be at present in their rules and practice, there would soon be great room for alterations and additions, owing to the varying conditions of trade. It was no intention of his to dilate at any length on classification, but there was one matter in the present rules might be referred to, which was, the steps or graduations of the tables. One scantling of material was given from one numeral to another, and represented a difference of two hundred tons in the size of the vessel in some cases. It appeared to him that this arrangement was directly encouraging the building of vessels closely up to the limit of each respective grade, and if a vessel, say of 3,000 tons, and as usual close up to the limit, was increased one inch in the dimensions, it would be found some twenty to thirty tons more material would be necessary to comply with the requirements for the next grade. Now, either the vessel just under the grade was too weak, or the one just over the grade was too strong; there was nothing very perfect or scientific in such rules and tables. He would suggest that their fixed scantlings should be looked upon, and dealt with, as spots in a curve, and to be only correct for a very small range, and instead of, say, increasing the thickness of all the outside strakes of shell plating at one jump, and increasing all the inside strakes at the next step or grade, let the increase be made one strake at a time by interpolation corresponding to the increase of the standard numeral towards the next. Spacing of the frames could be dealt with in a similar manner.

Another matter was, when passing sections at Lloyd's for a similar vessel it was found that tons of additional material were piled on without any warning, and this was a matter which punished shipbuilders severely. After getting all arrangements made to construct a vessel of given size, lines, and dead-weight, when plans were submitted it was no unusual thing to have ten or twenty tons of additional material added, the result being when the vessel was completed each additional ton of material cost £12 or £13, and then their esteemed friend the shipowner claimed a further £10 per ton for short dead-weight. This could be overcome in two ways, either making the vessel longer or fuller in the lines; but this was not always expedient, and it did not tell very highly in favour of Lloyd's rules, in another point of view, when it was considered that the displacement formed no factor in the case. A vessel might be ·55 coefficient or ·85 and the general scantlings remain the same. As to the question put by Mr. Macarthy, whether there was material for a North-East Coast Registry, he was not very clear about it; in fact, he considered if such a thing were gone into it should partake more of a national character.

They had heard a good deal about the representation of Lloyd's being so widely spread; but, as a matter of fact, the shipbuilders who contributed the bulk of the revenue had no voice in the administration. The underwriter was there in full force; of course that was only to be expected, seeing Lloyd's was essentially an underwriting concern. The shipowner was also there; but he (Mr. Macoll) decidedly objected to the statement that there was a fair representation of the interests concerned, when no shipbuilder, as a shipbuilder, was allowed within the charmed circle. Then even the much talked about freeboard tables, which no doubt involved an immense amount of labour, which few people had any idea of, in compiling and regulating, were, after all, the reflex of the practice of the better class of shipowners and shipbuilders. He knew steamers which had been stopped by the Board of Trade as unseaworthy, on account of overloading, which were now sailing with the sanction of the Board of Trade and Lloyd's with the same, and in some cases less freeboard than was originally marked on them by the builders.

Mr. Geo. N. Arnison, Jun., considered the subject of the surveying and classification of shipping, including, as it did, the fixing of the scantlings to which vessels had to be constructed, as well as the supervision of the building and the subsequent periodical and damage surveys, a most important one. In the paper read by Mr. G. E. Macarthy attention had been drawn to the question of establishing a "North-East Coast Register of Shipping," but from the general tone of the subsequent discussion it appeared that it was not considered probable that a new and successful surveying and classification registry could be organised. Men of experience who had participated in past efforts in organising and working a rival British Registry for Shipping were of that opinion, and they might be expected to know best. Even if the proposed new association had not only the North-East Coast but also the Clyde district as its principal centres of operation, success appeared far from certain. If, however, a new and powerful classification society, so desirable from several points of view, were not possible, surely there were sufficient grounds for carrying out the suggestion Mr. A. Scholefield made at the close of the discussion on October 21st, viz., that there should be a separate Committee of Lloyd's Register of British and Foreign Shipping for the North-East Coast as there was at Liverpool. This suggestion might well engage their attention, and if the meeting thought fit, he emphasised, such an arrangement would be of great value. For instance, in putting proposals before Lloyd's for classification if there were a

local committee, quicker despatch might be anticipated; but not only that, in cases of dispute with surveyors, which sometimes do occur, a special survey by the committee could be readily arranged if they were on the spot. Possibly it would emphasise the advantage of such an arrangement to quote one or two instances in which, under the latter aspect, a local committee would have been useful. A steamer was examined for survey on a neighbouring river, the damage being comparatively slight. The surveyor representing Lloyd's Register, in going round along with some one else thought he could see a fracture in the forward post of the stern frame, and decided that further examination was necessary, ordering off the garboard strake after plate, necessitating the cutting out of the rivets in the strake above, and entailing considerable expense. Ultimately it was found that the supposed fracture was just the original mark left by the welding of the stern frame. This should have been apparent on the first examination to the surveyor; possibly the owners' representative was not sufficiently firm. Had he (Mr. Arnison) been present he would have insisted upon a special survey and the presence of some one from the headquarters at London, before he acquiesced in the decision to remove the garboard plate. He happened to be interested in the vessel, and when the account came in and was submitted to the average adjuster a large portion was disallowed as the so-called defect in the stern post was an original defect, and no work in connection with it was chargeable to the underwriters. Thus the owners were fined in the amount of about £200 because of the excessive scrupulousness of the surveyor. Now, if they had had a committee sitting in Newcastle they might have said: "Would you just send your committee down to look at this?" and he doubted very much if practical men would have endorsed the view of the surveyor. Similar cases had occurred about minor points where there was not so much money involved. For instance, a vessel had touched the ground and was docked for sighting, and no internal damages were observable, but a hold stanchion which was not perfectly straight, and had long been in that condition, was ordered by the surveyor of Lloyd's Register to be removed and straightened, with the distinct statement that if it were not so dealt with the vessel's class would be suspended. He believed other shipowners and shipbuilders had similar experiences of occasional arbitrary acts on the part of individual surveyors. Mr. Macarthy had given them an instance when he had to resort to the Bureau Veritas for the classification of a vessel, and such instances showed the desirability of having immediate contact with the committee.

The question of scantlings had already been referred to, but it had been pointed out in the discussion that the scantlings required by Lloyd's Register were very unfair to fine-lined vessels, and [illegible] a premium for the building of full vessels. Whether a vessel was [illegible] of displacement it made no matter, provided the [illegible] and the principal dimensions were the same, the fine vessel having more less dead-weight capacity must have as heavy scantlings as the other with much heavier dead-weight carrying capacity. This was contrary to theory, and practice should be brought more into [illegible] with theory on this point. These were the principal matters that occurred to him in connection with this subject, and he hoped further consideration would be given to them.

Mr. G. B. Hunter (being called upon by the President) said it had been his desire to leave the discussion on this occasion more to the Sunderland members; but, perhaps, the President recognised that he was more a Sunderland man than a Newcastle man. He had not the pleasure of hearing the paper read; but, so far as time allowed, he would make one or two remarks which occurred to him. He thought it had been established from what he had heard and read of the discussion, that the consensus of opinion was that they did not require at the present time a local and rival register in the North of England. If Lloyd's should become more despotic than they were, and use their position in such a manner as to hamper either the business of the shipbuilder or shipowner, that time might come; or if Lloyd's should do as he thought they were not doing now—but as he thought they might be said to have been known to do in the past—stand in the way of progress, and interposed obstacles and difficulties in the way of shipbuilding or shipowning, then perhaps that time might come. But if that time came—he hoped it never would come; but if it did, he thought they would all feel that the new register of shipping should not be established as a local one, but should be established in London, and have all the standing and all the influence that that national position could give it. It should be a national register book and not a local one. However, he felt that Lloyd's Committee knew well their position, which rested upon meeting the reasonable wishes of those on whom they depended for support, and also upon their being ready to meet the requirements of progress and inventions; and he thought they were far too wise to place themselves in such a position as to necessitate the establishment of another and rival register book. Therefore he hoped that time might never come. He felt, as he said, that there had

been a time when they did not fully recognise the needs of their position, and when they might have been said to be something of an obstructive body, when they did not grasp with sufficient readiness the requirements of the new industry of iron shipbuilding, and when there was a need of a new register book being established. It was not only wanted, but was established with very great success; and it certainly served a useful purpose at that time. That time had passed, and although very friendly towards the Liverpool register, and recognising the useful work it did, as he (Mr. Hunter) grew older he felt more the evils of competition in such matters as the superintendence of the building of ships, on which not only the safety of property but human lives depended. He knew after the commencement of the Liverpool book there were evils from the amount of competition that took place; and one of the drawbacks from the usefulness of that competition was, that certain vessels were undoubtedly built below the strength found necessary for iron and steel ships.

However, that time had now passed; and as regarded the two great existing register books, that of Lloyd's and that of the Bureau Veritas, he supposed the only competition that existed was as to which should be most perfect, and which should be the first, if possible, to adopt any real improvements, and stand least in the way of invention and improvement as applied to shipbuilding and engineering. He thought they might say to the credit of Lloyd's—he hoped no Board of Trade surveyor was present—that it would be much better to be in the hands of Lloyd's Committee and under the rules of Lloyd's Register book than to depend entirely upon the Board of Trade. They might rely upon it that if it were not for Lloyd's they would be much more in the hands of the Board of Trade than they were. Whatever faults might be attributed to Lloyd's, their system was more elastic, and they entered into and met the requirements of shipbuilding and engineering better than the Board of Trade could do. He thought they might say this—he hoped he was not taking up too much time—that whatever difficulties they found in dealing with Lloyd's to the credit of the chief surveyor and his staff, be it said, whenever they went before Lloyd's Committee with a real grievance, they found they were ready to discuss it, and the chief surveyor, in his opinion, had always met them fairly, either by removing the grievance or by doing the next best thing, arguing it out, putting their views fairly where they were right or convincing them where they were wrong. He felt indebted to Mr. Martell for the tact and courtesy he had always shown on these occasions.

They must all feel this. He (Mr. Hunter) as a shipbuilder of many years' standing must say his experience of Lloyd's surveyors as a body was such that he respected them very much. He had always found them exceedingly courteous and obliging, and had never found Lloyd's surveyors make any requirement or raise any difficulty except in the most conscientious manner in the course of their duty. They must all feel there was not a more able and intelligent, a more obliging and courteous and honourable body of men in all Europe than the great body of Lloyd's surveyors. He felt bound to say that; and having said that, he might be allowed to add he did believe they had two grievances, including the one mentioned by Mr. Macoll. He thought they as shipbuilders and engineers ought to be represented on Lloyd's Committee as shipbuilders and engineers. It seemed to be considered unfit for them to occupy such a position, but he failed to see it. Shipbuilders as shipbuilders and engineers as engineers wished to elect representatives as members of Lloyd's Committee, which recognised as two of its most useful and honourable members, Mr. James Laing and Mr. William Gray, shipbuilders, although they were not there as shipbuilders. He (Mr. Hunter) felt that the efficiency and standing of Lloyd's Committee would not be diminished but greatly improved if shipbuilders and engineers were eligible by the constitution of the society for election on the committee. He thought they might claim the revision of the constitution to this extent as a right and it must come sooner or later.

There was another point in which he thought Lloyd's Committee stood in the way of the most perfect type of ship. He thought their rules distinctly encouraged the building of a class of ships which was not the highest type of ship, and that was the class of ship with long parallel "midship body," and box-like, full-lined ends so much built at the present time, but which, when he was a boy, would not have been considered ships at all. The next change, he ventured to predict, that Lloyd's Committee would make would be such a change as would discourage that type of ship, and allowed the element of displacement to determine to some extent, and probably to a considerable extent, the scantlings on which the ships were to be built. The displacement did not now enter into the calculation by which the sizes were fixed, and he ventured to predict, in spite of all that had been said to the contrary, that the time would soon come when that defect would be removed from the rules, and that vessels of fine form and easy lines would not be discouraged but encouraged by the element of displacement entering into the determination of the scantlings.

The PRESIDENT remarked that they had not had the opinion of any of the engineers present on the subject. He thought they should have something to say on the question as to whether a registry should be established on the North-East Coast or not. He should be glad to hear the opinion of some of those present.

Mr. A. G. SCHAEFFER (of Bureau Veritas) agreed that competition, in the ordinary sense of the word, was not desirable with shipping registrations. The high standard aimed at by Lloyd's and the Bureau Veritas might possibly suffer by the establishment of a number of competing registration societies, and he was therefore not in favour of a new local registry. He wished the rules and regulations of the two registries to be put on such a scientific basis as to be beyond reproach. Lloyd's would no doubt benefit by a representative of shipbuilders and engineers on the committee.

The PRESIDENT said he supposed they must consider this discussion brought to a close. In his opinion, it had been a most interesting and valuable one. They had had the opinions of many of their first shipbuilders and some of their shipowners, and he thought, to sum up the discussion, Mr. Macarthy must feel he had got the answer to the two questions he put so very forcibly in his paper. He did not think that these answers were at all condemnatory of the paper; on the contrary, he thought they had produced a large amount of information and of very valuable thought. There was one thing especially which the paper had brought prominently forward, and that was the necessity, in the opinion of this Institution, that they should have a representation of shipbuilders and of engineers at Lloyd's. That had been most forcibly brought out by the excellent and admirable speech to which they had just listened from Mr. Hunter. He did not want to follow up the whole of the speakers, but there was another speaker to whom he thought he must allude, and to the subject of his remarks, that was to the speech of Mr. Price. As the chief surveyor of the Liverpool Underwriters' Registry, and representative of the rival society in this district, his opinion on the subject of another registry was of the utmost importance and weight. He (the President) thought Mr. Price had conclusively shown that it was not necessary that they should have another registry on the North-East Coast, and that it would not be to the advantage of the shipowners of the district. Mr. Martell, too, brought very prominently forward one fact that went very far to answer the question put by Mr. Macarthy, that was: Was it desirable to have, or practicable to have, a registry on the North-East Coast? when he gave

the amount insured in the various ports of the country. He showed them that while Mr. Macarthy very graphically brought out something like twelve millions of policies represented on the North-East Coast, afterwards corrected by Mr. Milburn to sixteen millions, there were six hundred millions represented in London, and as the classification of vessels existed for the purpose of underwriting and assessing values of vessels, and that a large amount of these policies were policies on the vessels, he thought that fact sufficiently answered the question as to the relative importance of having a registry here—the importance might be said to be in the relation of 12 to 600. But however important, it had led to the elucidation and letting in of the light on the relations of Lloyd's institution and that of the Bureau Veritas in regard to the shipment of petroleum in bulk, and he thought very much to the advantage of the Bureau Veritas. In regard to the advantage of competition, they had enough competition in their daily life, and the less they had in their theoretical and scientific questions the better. He should have liked to have heard some of their engineering friends on the question, but he had no doubt their views would have accorded very much with those of the shipbuilders, viz., that, while they wanted representation, and to have something to say on the now very important functions which Lloyd's fulfilled, on all engineering questions, that it was scarcely desirable or necessary that there should be a local registry. In regard to forming a branch of Lloyd's in this locality, he thought this a very fair matter for discussion. Where they had such a large extent of shipbuilding as they had on the North-East Coast, it did seem to him to be of advantage that they should have the means of communicating with a body of gentlemen who could give an answer on many questions without submitting it to London, and he thought it a subject worthy of the energies of this Institution, to seek to have a branch here. After all, it was not so much the shipowner who had strictly to do with the construction of his vessels, it was the shipbuilder, and, however largely he had to consult with Lloyd's, he was the constructor of the vessel, and any questions that might arise under that construction did rest with the shipbuilder. Here they had on this coast a very large industry, with a larger number of shipbuilders, putting the three rivers together, than almost any other district; he therefore thought it would be only the right and proper thing to have a branch of the committee sitting in Newcastle, as well as in Liverpool, and also in Glasgow—he thought the same thing applied to Glasgow as to themselves—and it would facilitate the various operations they had to carry out in conjunction with Lloyd's Committee. He would now call upon Mr. Macarthy to reply to the discussion.

Mr. MACARTHY asked the members to bear patiently with him a short time if he went over again much that had already been spoken to, as statements had been made which required to be refuted. The Institution had wisely, he thought, widened the basis of its constitution by opening its doors to shipowning Associates; but shipowners, as a body, were not scientific experts, and when the Secretary asked him to write a paper, it was, as he (the Secretary) would bear him out, with considerable hesitation that he acceded to his request. In his opening remarks he stated that he did not intend to deal with the subject of the surveying and classification of shipping in a technical or scientific manner; but he was not disposed to yield to anyone with respect to his competency to deal with the commercial or economic bearings of the question, having been engaged since 1854—a period of 35 years—in the shipping trade, watched and taken part in the growth and progress of our great steam-shipping industry, and shared in its changes and vicissitudes. This personal statement was drawn from him by the remarks of two speakers in the early part of the discussion, who had misinterpreted (he would not say misrepresented) his meaning, and charged him in somewhat harsh terms with writing upon a subject about which they assumed that he was in ignorance.

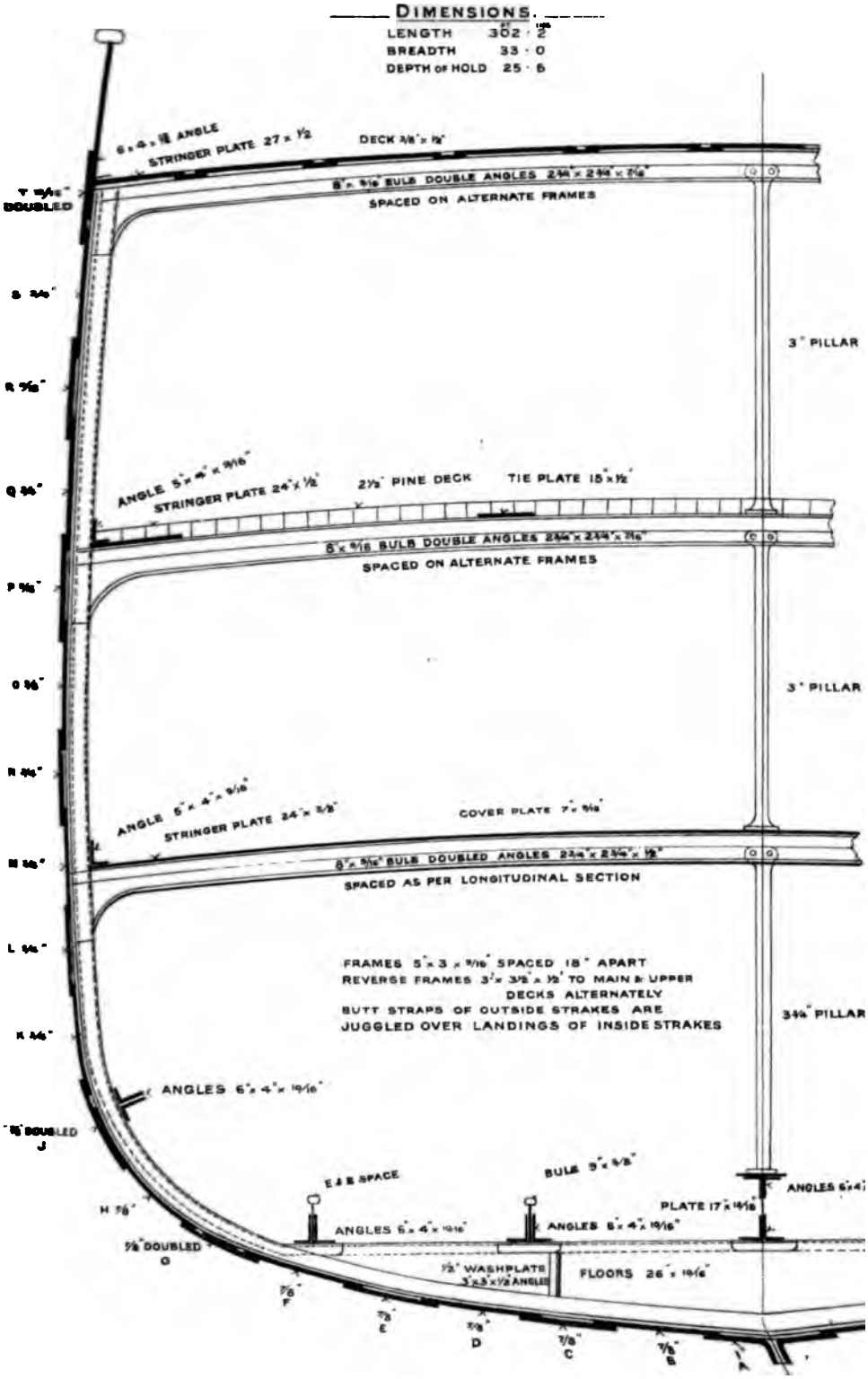
Mr. Wigham Richardson, although he was of opinion that it would not be wise to contemplate the difficult task of starting a new registry, discussed the question in a fair and judicial spirit. He was opposed to the centralisation policy of Lloyd's, and suggested that the fullest powers should be delegated to a committee strengthened by representatives from the Naval Architect section of its dues-payers, who shall have their place of meeting close to the shipbuilding establishments. He also suggested that, with respect to the Bureau Veritas, the shipbuilders should come forward and assist to see that fair play shall be done by the English Government. By the latter he (Mr. Macarthy) understood Mr. Richardson to mean that in tenders for Admiralty and other Government freight contracts shipowners shall not be tied down to Lloyd's classification only, but that they shall also be allowed to employ vessels classed in the Bureau Veritas. He quite agreed to these suggestions, and they in part confirmed his contentions.

Mr. Arthur Coote, whilst giving a general support to Lloyd's, also claimed a larger and more direct representation.

Mr. John Price, after indulging in some rather caustic remarks at his (Mr. Macarthy's) expense, which were, by the way, disputed in his statements, dubbed the paper and his illustrations unfortunate, and asked

To illustrate Mr Macarthy's Reply to the Discussion on his Paper.

MIDSHIP SECTION S.S. "ISIS."



certain questions; but as Mr. Martell, who followed him, took up very much the same ground, his reply to Mr. Martell would serve for both gentlemen. He might, however, point out that Mr. Price also told them that "the Liverpool Committee made them (Lloyd's Committee) feel they rested upon a more popular support, and now they wanted this basis a little more widely extended;" and further on he said—"What they wanted was to have Lloyd's wisely infused with that element by which the construction of ships was alone understood, and he thought they would prevent the elements from clashing. They would, that is to say, exclude errors from the construction of a ship and bad administration in the conduct of the society." He (Mr. Macarthy) asked was not this the case for the plaintiff?

Now for Mr. Martell. He was pleased that he (Mr. Martell) should have taken the trouble of coming to their former discussion, and that they should have heard all he had to say in defence of his society. He thought, however, if he might be allowed to say so, that he might have shown more courtesy to him (Mr. Macarthy) in particular, and to the Institution generally without injury to the cause he came to advocate. Such expressions as "misrepresentations," "misleading statements," "sinister influence," "garbled account," "not a truthful statement," were not what they were accustomed to in the discussions of this Institution.

He (Mr. Martell) told them there was nothing in the paper to discuss, and he occupied more than thirty minutes in discussing it. He rated the Council of the Institution for passing it, but he ought to allow them to be the best judges. After all was said the engineers, shipbuilders, and shipowners were the bodies from whom Lloyd's Society derived nearly all its revenue, they were, therefore, quite in order and competent to criticise its constitution and work.

Mr. Martell thought "there was something behind the scenes, he could not tell what." He (Mr. Macarthy) assured him there was nothing behind the scenes, all was straightforward and above board so far as he was concerned. The petroleum tank steamer question was he presumed, according to Mr. Martell, one of the misrepresentations contained in the paper. He ventured to say, however, that the misleading statement was Mr. Martell's and not his. The type of steamer he referred to was not the double skinned vessel of 1872, alluded to by Mr. Martell, and which he believed was never put into commission, but the modern boat of the "Bakuin" type, built in 1886 by Messrs. Wm. Gray & Co., of West Hartlepool, against which there appears a foot note in Lloyd's Register of 1888-9, "Classification does not extend to petroleum fittings," and on

this point Messrs. H. F. Swan, B. G. Nichol, and J. Gravell corroborated his view as to the obstructiveness of Lloyd's (the word was Mr. Martell's); and here he thought it was due to Mr. Swan, as he seemed to be somewhat anxious on the point, to state that he had absolutely nothing to do with the paper nor did he believe that he had any knowledge of it previous to their last meeting. The first and only occasion when he had consulted Mr. Swan on the subject of petroleum steamers with tanks carried to the outer skin was in July, 1885, when, if his memory served him right, he gave him (Mr. Macarthy) to understand that a classification for such a steamer could not be obtained from Lloyd's, and he, thereupon, abandoned the project, thereby losing a most profitable contract.

Now, with respect to the well-deck steamer and the load-line question he was sure that his shipowning brethren would support his contention, that considerable friction had existed with Lloyd's for some time, and that it was only after the very great efforts of Mr. Yeoman, of West Hartlepool, to whom they (the shipowners) owed a great debt of gratitude, that Lloyd's Committee were brought to take a reasonable view of the question. Mr. Martell asked how much information he had given in bringing this question to maturity. Well, he would tell him. On the 23rd of March, 1882, he supplied Lloyd's Committee with particulars of ten steamers, for none of which could he accept their load-line basis in place of the freeboards he had assigned himself on the advice of competent masters, proved to be perfectly safe after many years' sea experience in all weathers, and none of the steamers under his management had foundered or suffered at sea through overloading. Mr. Martell told them that until Lloyd's took the matter up, the Government prevented them sailing their ships properly. He (Mr. Macarthy) warned the members of that Institution, and through them the shipowners and shipbuilders generally, to beware of this flirtation of the Board of Trade with Lloyd's, for some fine day it might eventuate in an alliance with the "Barnacles" of that circumlocution office that would bode ill to their shipping interests.

Referring to the steamer which Mr. Price termed apocryphal, and of which Mr. Martell said it would have been more honest if he (Mr. Macarthy) had told them it was his own. Mr. Martell was quite correct as to the steamer being under his (Mr. Macarthy's) management; but if he had endeavoured to exclude the personal element from the discussion he failed to see where the dishonesty was. Mr. Martell said his account with respect to this steamer was untruthful, and to this he replied that, if he would pardon him a little exaggeration in the expression "riddled like a sieve," he was prepared to substantiate his statement. Mr. Price asked

him how did he know that a committee sitting in Newcastle would have settled the question as to this steamer in 24 hours? and he must admit that it would be very difficult to prove how a hypothetical committee would act. That is the midship section of the boat as she was presented for survey (*pointing to a plan on the wall*—See Plate II.), and if Mr. Price cared to take the trouble, he would be pleased to give him an early opportunity of judging for himself. Mr. Martell told them that the insurances effected in London amounted to £600,000,000, and from reliable information he learned that this was the annual amount; and he also told them that he (Mr. Macarthy) was quite right in fixing the amount of the North-East Coast insurances at £12,000,000. Apparently, however, on this only point upon which Mr. Martell was prepared to agree with him, he (Mr. Macarthy) was in error, as, according to Mr. Milburn, the amount should be £16,000,000. Now, figures are ofttimes deceptive. The North-East Coast insurances were mainly upon hulls, at an average premium of about 8 per cent. per annum, whereas the bulk of the London insurances were on cargoes, the premiums on which were, in some cases, very low. Take, for instance, the local coasting cargoes to London, on which the premium was 2s. per cent., the underwriter would require to underwrite £8,000 to net the same premium as £100 at £8 per cent.

Mr. Arthur Scholefield, whom he had to thank for giving him a certificate of character, suggested that we should, if possible, get a branch of Lloyd's for the North-East Coast.

Mr. J. D. Milburn, as a member of Lloyd's Committee, was naturally careful not to condemn that society. By the necessity of his position his mouth was closed.

A verbatim report of the first evening's discussion had appeared in the *Shipping Gazette* of the 23rd October, and their old friend "*Fairplay*" had taken up the cudgels and for two weeks running had tomahawked and scalped him (Mr. Macarthy) in his usual Red Indian style. He was of opinion that it would be fairer to writers of papers, if in future the newspapers were to be supplied with reports, that they should be supplied with the discussions in a complete form.

In conclusion, he begged to state that in his efforts to be brief he had unavoidably left much unanswered. He had to thank the members of the Institution for the patience and attention they had given to the consideration of his paper. He was free to admit that the consensus of opinion appeared to be adverse to the starting of an independent registry; yet if, as a result of the discussion thereon, the ruling powers at Lloyd's and the Bureau Veritas should see fit in the near future to establish branch

committees on the North-East Coast, he should have the satisfaction of knowing that he had not raised this storm in vain.

The SECRETARY (Mr. J. Duckitt)—In reply to Mr. Macarthy I can assure members I know nothing whatever of the report in the *Shipping Gazette*.

The PRESIDENT said the one duty that now devolved on him was to move that their hearty thanks be given to Mr. Macarthy for his very useful and interesting paper. He was sure they had listened in the first instance, with interest, and they had listened to his reply, in all respects a courteous and worthy reply, with very great pleasure and satisfaction. He would just like to say in regard to Mr. Macarthy's remark as to the report of their proceedings, he was afraid in these days of a free press, it was very difficult to withhold the report of proceedings like their own. It was one of the complaints of all scientific institutions that incomplete reports of papers and discussions did get into the papers. If Mr. Macarthy only thought for a moment he would remember that a full account appeared in each of the Newcastle papers the morning after the discussion, and so far as he had seen the reports alluded to they were almost a reprint of the Newcastle papers' reports. He thought that would satisfy him that none of the staff of the Institution—of the North-East Coast Institution of Engineers and Shipbuilders—had anything to do with the matter. He had now the honour of proposing that their hearty thanks be accorded to Mr. Macarthy for his very valuable paper.

This was carried by acclamation.

The following communication has been received from Mr. T. McNabb:—

COMMUNICATION FROM MR. THOMAS MCNABB.

NEWCASTLE-UPON-TYNE, *9th November*, 1889.

DEAR SIR,—I regret that circumstances prevented me attending your meeting at Sunderland last night, as I had intended to speak at the adjourned discussion on Mr. Macarthy's paper, read at Newcastle on the 21st of October last. I consider that the main object of the paper was lost sight of at the Newcastle meeting, and the observations of the speakers were wide of the object for which the paper was prepared. The question was, as to the practicability or advisability of forming a Registration Association for Shipping on the North-East Coast. My impression is that such an association would be beneficial, in the sense that competition is desirable in most things; and without doubt the shipping community at large, and even Lloyd's, benefited by the Liverpool Registration Association started a good many years ago.

Another reason for advocating this is, the advisability of having an association at hand that could decide upon details of construction promptly, without the necessity of going all the way to London. In fact the tendency of the age is decentralisation.

I have no animus against Lloyd's as such, but I do remember that the influence of the Liverpool Registry was beneficial to the shipping community, in so far as it forced Lloyd's to modify their rules in the direction of a more scientific adjustment and distribution of materials and weights in relation to the structure dealt with.

I think I am justified in stating that if Mr. Richardson had been permitted to continue his speech, he would have shown that vessels built ten, twelve, or fifteen years ago, according to the rules of the Liverpool Association, had the scantlings better arranged; that, given two vessels of similar dimensions, the one built according to Lloyd's rules of that day, and the other according to the Liverpool rules, the latter would carry more cargo and be a stronger vessel.

A shipbuilder and draughtsman, of the highest standing on the Tyne, prepared some years ago plans of vessels built according to the rules of the two societies, which clearly showed to the advantage of the Liverpool Registry. The Liverpool society did good while it lasted, and I think it a pity it should have been allowed to lapse. When the Liverpool society was initiated it could not have had the support which a new society for the North-East Coast, and embracing the Scotch ports, would have at the present time; therefore if it was expedient to inaugurate a society in Liverpool at that time, it could not be inexpedient to inaugurate a similar one on the North-East Coast now. I think I am justified in saying that there is a very much larger amount of tonnage and of capital obtainable to start with than was the case when the Liverpool association began.

With respect to the remarks made as to the values insured in London, Liverpool, and Glasgow, I don't think that has anything to do with the question. It is singular that, whereas in 1883 a very strong movement was made here for a like purpose to that now advocated by Mr. Macarthy, those who were so prominent at that time in endeavouring to get up an East Coast Association should now throw cold water on the present scheme. I have an idea of my own as to the reason, which may be wrong, therefore I won't state it.

Subsequent to Mr. Richardson's remarks, the discussion at Newcastle became personal, fault was found with Mr. Macarthy commencing his paper by modestly stating he was not technically acquainted with the subject. It is a very common thing for people coming before such an

Institution as ours to preface their remarks, or their paper, in this way, and I don't think that modesty of that sort is so objectionable as to call forth the sneering remarks made by certain speakers. I think a little modesty is rarely, if ever, out of place.

Mr. Price seemed to me to take Mr. Martell under his wing. *Esprit de corps* is an admirable quality, but did that quality exist so strongly fifteen years ago when the Liverpool Registry was in existence in reference to Lloyd's?

With regard to Mr. Martell's speech, which I consider was quite out of place, as if Lloyd's had been in any way attacked, it should have been left to some of the local representatives, who are members of this association, to have taken up the cudgels. The speech in question was in the very worst taste, and, however effective as a piece of declamation, did not touch the particular object of the paper.

In reference to the particular question of oil tank steamers, Mr. Swan let Mr. Martell and Lloyd's down very lightly. Whatever Mr. Martell may now say, at any rate, in August, 1885, when I went to him with a view of getting a vessel classed, or class continued, as an oil tank steamer carrying the oil against the skin, he, as the technical adviser of Lloyd's at the time, absolutely vetoed my scheme, and could only see as far as "Svets'" arrangements. It is all very well for Mr. Martell to say now that they did not put any obstructions in the way of oil tank steamers, but, as a matter of fact, they did in my case, and I believe Mr. Swan holds the same opinion. The reasons given by Lloyd's for refusing to allow the oil to be carried to the skin were so puerile that I wonder anyone of common sense, much less a man of Mr. Martell's attainments, would have given expression to them. I do not presume to speak for Bureau Veritas, Mr. Richardson said all that I would feel disposed to say; but this I do say, my deliberate opinion is, that had it not been for the action of Veritas in relation to oil tank steamers, Lloyd's would have left us where they said we should remain in August, 1885. So far as the local officers of Lloyd's are concerned, I have had much to do with them, I have the very highest opinion of them, and I do think a more worthy body of public servants could not be found. But that does not settle the objection to the action of Lloyd's as a registration association, nor does it dispose of the value or merits of Mr. Macarthy's paper as to the "advisability or practicability" of having an East Coast Registration Association. I think we ought.

Yours truly,

THOMAS MCNABB.

THE STRENGTH OF BOILERS.

By JAMES C. SPENCE, M.I.N.A.

[Read before the Institution on November 8th 1889.]

For many years the opinion has been gaining ground among engineers that the rules at present in force prescribe a greater thickness for the shells of marine boilers than practical experience shows to be necessary. The engineers of H.M. Navy, acting on this experience, have recently made great reductions in the thickness of the shells, without making any corresponding reduction in the thickness of other parts of their boilers. Mr. A. C. Kirk, speaking at last year's annual meeting of the Institute of Naval Architects said, that if the designers of boilers for the mercantile marine were their own masters, and not subject to official control, they would long since have altered their practice in the same direction.

The object of this paper is to bring before this Institution a new method of calculating the strains on boilers which, if correct, would allow of making enormous reductions in the thickness of marine boiler shells, without making any reduction in the factors of safety or any radical change in the designs. An examination of the present theory on the subject, and a reference to one or two elementary principles, will put in a clear light the difference between the proposed theory and that now in use.

Fig 1, Plate III., represents a narrow section through a cylindrical vessel subject to internal pressure. For good and sufficient reasons we reckon that the pressure tending to rupture this ring is equal to its diameter, multiplied by its length, multiplied by the pressure per square inch; that this pressure is resisted by the tensile strength of the two sections, A A and B B; and is measured by twice the thickness of the ring multiplied by its length, multiplied by the tensile strength of the material of which it is composed. Reasoning on this basis we find that the strength of such a ring may be expressed as a fraction thus:

$$\text{factor of safety} = \frac{2 \times \text{thickness of ring} \times \text{length} \times \text{strength of plate}}{\text{diameter} \times \text{length} \times \text{pressure}}$$

And as the length of the ring affects to an equal extent both the bursting pressure and the section resisting bursting, it may be cancelled from both sides of the fraction. Hence we infer that the strength of a ring varies directly as its thickness, and inversely as its diameter, and is independent of its length.

As all cylindrical vessels may be considered as made up of a series of narrow rings, it is assumed that their strength is independent of their length, that it varies directly as the thickness of their shells, and inversely as their diameter.

This generalisation is adopted without modification as the basis on which the shell scantlings of all cylindrical boilers are proportioned. It is accepted without question by all practical men, even by those who are vaguely conscious that it prescribes an excessive thickness. It is taught authoritatively by all professors and writers on the subject, and it is enforced by all the power of the double censorship—Board of Trade and Lloyd's—under which engineers are forced to work. But as it is of much greater importance to have our practice right than to be unanimous in our theory, the writer asks you to weigh, with minds unbiassed by this weight of authority, the arguments which he considers prove that our present theory is absurdly wrong—that it is a fraction of the truth mistaken for the whole truth.

For a boiler is not an open ring, nor a series of such rings, but a structure composed of a short ring and two strong ends. The strength of the structure is partly dependent on the strength of the ends, and the proportion of length to diameter is not, as we have hitherto supposed, a matter of indifference, but a matter of vital importance.

To make this evident we have only to examine an extreme case.

A A (Fig. 2, Plate III.) is a flat boiler plate $\frac{3}{8}$ of an inch thick, riveted to two strong flanged plates B and C, 12 inches apart, and having an unsupported strip 6 inches wide between flanges. This plate would be capable of standing a pressure of 100 lbs. per inch. To roll this plate into a circle would certainly not weaken it, and therefore if B and C were to represent the ends of a cylinder 1 foot long, and A A represented the shell of that cylinder, then we might make the diameter of that cylinder as great as we pleased without any increase in the thickness of shell, which would never be weaker than a flat plate, and as the length of section of end plate resisting rupture would increase directly as the diameter, we might safely assume that the whole bursting pressure would be borne by the ends, and neglect as of no account the strength of shell plate. In fact, the greater the diameter of this short cylinder, the more evident it is that its strength depends on its ends and not on its shell.

From this point of view, the strength of cylindrical vessels, with ends securely fastened to shells, depends on the resistance to rupture of the shells and the ends. In very long vessels the shell bears such a large proportion of the total strain that we may leave the ends out of our calculation. In very short vessels the ends bear so large a proportion of

the total strain that the strength of the shell may be ignored; but in marine boilers, where the ratio of length to diameter approaches equality, it cannot be safe to deal with either factor as the sole one.

We have now to consider the distribution of strain on the different parts of shells and ends of short boilers.

Fig. 3, Plate III., represents a rectangular box 15 inches long × 10 inches wide, closed with a flat lid. If this were filled with steam, at a pressure of 100 lbs. per inch, the pressure tending to lift this lid would be 15 × 10 × 100 = 15,000 lbs. No one who has ever adjusted, or even seen, a weighted lever safety valve, can doubt that a single weight applied directly over G, the centre of the rectangle A B C D would exactly balance the internal pressure. We also know that the shape of the lid of this box might be altered to any form we pleased, and the total weight and the position of its resultant would remain unaltered. The lid might be made as shown in Fig. 4, Plate III., a half cylinder 15 inches diameter × 10 inches long; or it might be made as shown in Fig. 5, Plate III., a half cylinder 10 inches diameter × 15 inches long. Still a weight of 15,000 lbs. applied at the centre G of the rectangle would exactly balance a pressure of 100 lbs. per inch in the box.

Instead of balancing the pressure of steam on the flat lid (Fig. 3, Plate III.), by a weight applied over its centre we might balance it by bolting the lid down with the bolts shown in Fig. 6, Plate III. Now, if a load is supported by two or more supports the pressure on these supports will be equal if they are equally distant from the load, but if they are unequally distant from the load then the pressure on each support will be unequal, the nearest support getting the most, the most distant the least part of the pressure. The pressure on each support varies inversely as its distance from load. Looking now at Fig. 6 we see that the strain supported by the bolts in the flange is exactly equal to a single load at G, and the bolts are not all equally distant from this point. Thus the bolt marked 1 is the nearest, 2 is the most distant, and 3 is intermediate between these. The dotted column over each of these bolts shows the relative pressure on each, which is greatest over 1, least over 2, and intermediate over 3.

If instead of the flat lid, we were to close the box by lids shaped like Fig. 4 or Fig. 5, Plate III., but held down by bolts, arranged as in Fig. 6, Plate III. Then in all three cases—the flat lid, the short cylindrical lid, and the long cylindrical lid—the total pressure would be the same, the position of resultant would be

the same, and consequently the strain on each bolt must necessarily be the same. This strain is absolutely independent of the form of the cover, it depends only on the distance of the bolt from the centre of rectangle. If this is true then it follows that if Fig. 7 and Fig. 8, Plate IV., are two cylindrical vessels, one of them being 15 feet diameter × 10 feet long, the other 10 feet diameter × 15 feet long, both subject to a pressure of 1 ton to the foot, then the pressure tending to burst these vessels in any direction, say for instance, to lift the top half from the bottom half, is in both cases 10 feet × 15 feet × 1 ton = 150 tons. In both cases this pressure has a resultant passing through G the centre of the rectangle. In both cases the metal in the plate sections A B, B C, C D, and D A resist this pressure; and in both cases the strain at any point in this plate section is independent of the form of the top and the bottom half, but depends solely on its distance from G.

Fig. 9, Plate IV., gives a diagram of the strain coming on each point of a rectangle 15 feet × 10 feet on the hypothesis that the strain at each point varies inversely as its distance from G, it is greatest at D when the distance G D is least, it is least at C where the distance G C is greatest, at B the strain is less than at D in the proportion of $\frac{G\ D}{G\ B}$. The area of the curved figure A K M C represents the total strain on A C. The area of C N P E represents the total strain on C E.*

We can now make a complete comparison between the theory hitherto in use and that offered for your consideration. Both theories assume that the bursting pressure on each of these sections (Figs. 7 and 8, Plate IV.) is the same in magnitude and direction; but the first of these assumes that in each case the total strain is borne by the shell plates B C and A D, that this strain is distributed uniformly along these lines, and that there is no strain on end plates A B and B C. While the second theory assumes, that the total strain is distributed over each point of the section resisting fracture, that it varies inversely as the distance of each point from the centre of the section, and that it is the same on each point of the rectangle (Fig. 7, Plate IV.) as in the corresponding point of the rectangle (Fig. 8, Plate

* If (A) and (B) are two sides and (C) is the diagonal of a rectangle subject to a strain varying as above then—

$$\frac{\text{The total strain on (A)}}{\text{The total strain on (B)}} = \frac{\log.\left(\frac{A + C}{B}\right)}{\log.\left(\frac{B + C}{A}\right)}$$

IV). This of course assumes that the structure is strong enough to stand the pressure brought upon it. If, for instance, the end plate in Fig. 7, Plate IV. were too weak, and either fractured or stretched beyond its elastic limit, then, and then only, a greater strain might come upon the shell plates than is here estimated, but until the end plates are fractured or crippled they must bear their due proportion of the strain.

If this new theory is correct, we can now see the magnitude of the errors we have been committing. The area of C N P E (Fig. 9, Plate IV.), is very nearly twice the area of C M K A, and consequently in a boiler 15 feet diameter × 10 feet long, only one-third of the total pressure comes upon the shell plates and two-thirds on the ends. In a boiler 10 feet diameter × 15 feet long, two-thirds of the total comes upon the shell and one-third on the ends. It is also evident that if the diameter of a boiler equals its length, its section will be a square, and the strain on each of the four sides of that square will be equal, and therefore one-half of the total strain will be carried by the shell, one-half by the ends. That is to say, if we allow for the strength of the ends as well as the shells, then—

In a boiler where diam.	=	$\frac{2}{3}$ length,	shell-plates	$\frac{2}{3}$	the	thickness	now used	would suffice.
" "	"	= length	"	$\frac{1}{2}$	"	"	"	
" "	$\frac{2}{3}$ diam.	= length	"	$\frac{1}{3}$	"	"	"	

If it is true that the ends of boilers bear the above share of the pressure, tending to rupture the cylindrical shells, then the theory that tells us that we may neglect their strength has led us into other errors, besides that of wasting material in making our shells excessively strong. For while we have been racking our brains to save another half percentage of plate section in shell plates, we have riddled our end plates with tube holes, and cut out great holes for furnaces and doors, as if in fact, as in theory, their strength was of no importance. That no disaster has resulted from this may be due to the fact that we have vast reserves of strength never considered, that our furnace holes are compensated by strong furnaces, and that we have a large factor of safety which covers a multitude of sins.

Again. If a boiler is made throughout of uniform strength, all the parts will elongate together, if the pressure exceeds the elastic limit of the material the rivet holes will elongate so that leakage will prevent any explosion or sudden fracture, but if our boilers consist of very strong shells and weak ends, we run the risk that fracture might take place through a weak part of front, before the uselessly strong joints of shell

commenced to leak. That is to say, in a boiler where the strength of each part is proportioned to its strain, the worst risk we run is that of leakage, but in a boiler where the greatest strength is put where the least strain comes we run the risk of explosion.

At this point our argument might be concluded, but as it assumes that we have all been led astray by what seemed to be perfectly sound reasoning, can we venture to revolutionize our practice in accordance with this new theory? To this it might be answered that it is better to trust to a theory which allows for two factors in a problem, than to a theory which avowedly neglects one of these factors, especially when we find that the neglected one is frequently the most important of the two. There is, however, a much better answer than this, there is ready to our hands actual experimental proof, not only that the old theory is wrong, but also that the new theory here propounded is a very close approximation to the truth.

This proof is to be found in the series of experiments recently made by Mr. John Scott, who read a paper on the strength of boiler shells at the last meeting of the Institute of Naval Architects. The figures, facts, and arguments brought out in this discussion are now to be considered.

Mr. Scott built a boiler 7 feet 8 inches diameter × 11 feet long, consisting of shell, ends, and stays, omitting furnaces, combustion chambers, and tubes. He tried to test this to destruction, but only succeeded in making it leak. This result admits of a very simple explanation. The shell was built of steel plate, having an elongation of from 25 to 29 per cent. This elongation, as you are aware, is not produced uniformly. Below the elastic limit the elongation is so small that it requires delicate measurement to detect it, but when the strain reaches this limit the elongation increases rapidly and suddenly, at the same time, the area of the section begins to contract rapidly. A test piece slightly elongated by a strain below its elastic limit, returns nearly to its original condition when the strain is released, but when the strain has exceeded that limit the piece remains stretched and the area contracted.

Now, it is evident that a boiler built of steel of this description can not be strained by water pressure to much above the elastic limit of the structure, for at this point the rivet holes would all begin to stretch rapidly, and the thinning of the plates would destroy the efficiency of the caulking, and a boiler with rivet holes stretched and caulking started could not hold water at a high pressure.

This is exactly what happened with Mr. Scott's boiler at a pressure of 620 lbs. to the inch—the leakage overpowered the pumps. Having a very large water supply they were able to keep up this pressure for five minutes, but unable to increase it. When the pressure was reduced it was found that it had produced no fracture, and no serious disturbance of the structure, proving that the elastic limit had not been greatly exceeded. For had the strain approached the breaking strain of the material the experimenters would have seen a very serious disturbance of the structure. They would have seen it swelling visibly before their eyes. These considerations and a comparison of the final test with previous tests, at lower pressures, show that the strain on shell plates had reached and passed the elastic limit, but they also show that the strain was far below the point of rupture.

Now, if the old theory that all the pressure came on the shell was correct, then the strain on the solid plate of shell was 78 per cent. of its ultimate strength = 22 tons per inch; the strain on shell plate in line of rivets was 93½ per cent. of its ultimate strength = 26 tons per inch, and under that strain the boiler held water at a pressure of 620 lbs. for five minutes. Yet Mr. Manuel, in the discussion that followed the reading of this paper gave a series of tests with a riveted joint similar to that used in the experimental boiler, and showed that the elastic limit was reached at 15¾ tons per inch; that the joint was to all intents and purposes crippled as a joint, with a strain of 20 tons to the inch, although it did not finally rupture till the strain was 28·7 tons to the inch. And we are supposed to believe that this boiler held water for five minutes at a pressure of 620 lbs. when strained to 26 tons to the inch.

If, however, we allow for the strength of the ends (as in Fig 9, Plate IV.), we find that only 63 per cent. of the total strain comes on the shell, 37 per cent. coming on the ends. On this hypothesis, the strain on shell plates, under a pressure of 620 lbs., was 16¼ tons to the inch.

Now, Mr. Scott gives the elastic limit of plates, similar to those used in his boiler, as 16½ tons. Mr. Manuel gives the elastic limit of joints as from 14 to 16 tons. This boiler, which all the evidence proves to have been strained just above its elastic limit, sustained a pressure, according to the new theory, of 16¼ tons per inch, according to the old theory of 26 tons per inch. The inference drawn by the writer is that the old theory is wrong and the new one is right.

Let us now conclude this paper with a short summary of the arguments used therein. After noting that practical experience had led many engineers to the conclusion that the rules now in force prescribe an

excessive thickness for the shell plates of marine boilers, we examined the theory on which these rules are based, and found that it was a theory only true for open-ended rings, which might be approximately true for long boilers; but for short boilers of the marine type was manifestly untrue. We then considered the case of a very short boiler, and saw that in such a case the strength of the shell instead of being the sole consideration was a small fraction that might be neglected, and the whole strength of boiler to resist rupture might be reckoned as that of the end plates.

We then, by reference to the simplest and most elementary facts, showed that the distribution of strain on a given section did not depend on the form of the vessel of which the section was a part, but only on its area and pressure. From this we inferred that in two boilers of which the length of the one equalled the diameter of the other, as these would have a rectangular section equal in all respects to each other, the strain at any point in this rectangle would be precisely the same for both boilers.

We then estimated the difference of the thickness of shell plates prescribed by the old and by the new method, and found in three typical proportions of boilers that—

In one case the old rules require a thickness one half greater than the new theory.

In another case the old rules require a thickness twice as great as the new theory.

In a third case the old rules require a thickness three times as great as the new theory.

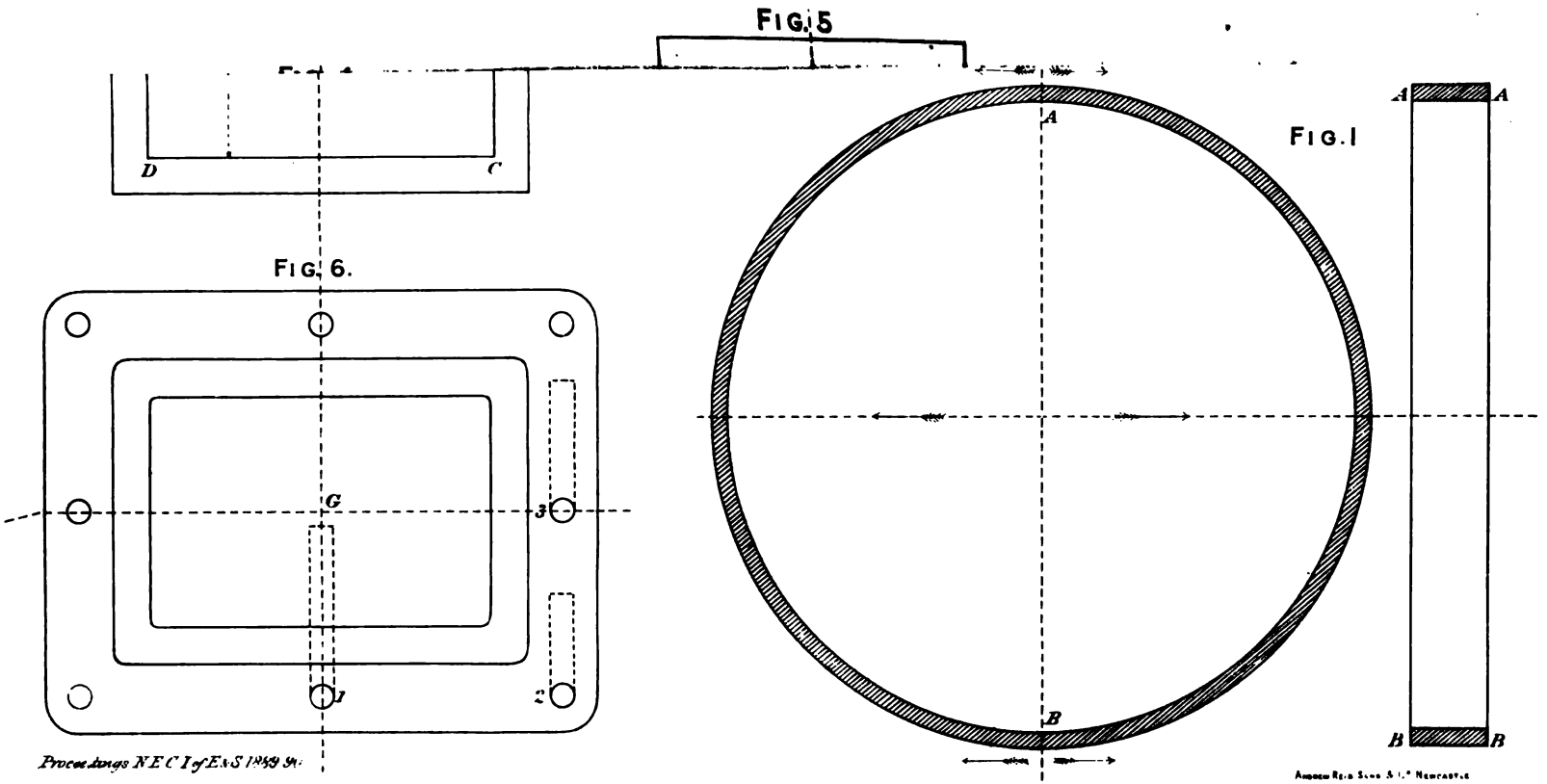
We then noted that if the new theory were correct, then our old theory had led us to commit, at least, two other serious errors. And finally, by an appeal to the best and most recent experiments on the strength of a boiler, we found that these experiments were inconsistent with the old theory, and agreed with great exactness with the new one.

The two theories are now before you, and it is for you to choose which you will trust—the old theory, which ignores one-half of the problem, or the new theory, which takes account of both elements in the strength of short boilers.

The President said they had heard Mr. Spence's paper, and had still some five or ten minutes for discussion; but it appeared to him it would be better to think the subject over, and be prepared to discuss it at the next meeting.

This suggestion was agreed to, and the meeting dispersed.

To illustrate Mr. James C. Spence's "Paper on the Strength of Boilers."



NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

SIXTH SESSION, 1889–90.

PROCEEDINGS.

THIRD GENERAL MEETING, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON MONDAY EVENING, DECEMBER 16TH, 1889.

F. C. MARSHALL, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the preceding General Meeting, held in Sunderland, on November 8th, which were approved by the members present and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. A. Taylor and M. Sandison to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Bastow, William W., 112, Scarborough Street, West Hartlepool.
Bodin, Lauritz M., 27, Argyle Square, Sunderland.
Brown, George, c/o Messrs. C. S. Swan, Hunter, & Co., Wallsend-on-Tyne.
Casebourne, Charles Baston, Greatham House, Greatham, near West Hartlepool.
Coulson, Robert, Fountain's Terrace, West Hartlepool.
Cowens, William Edward, c/o Messrs. John Abbot & Co., Gateshead-on-Tyne.
John, Edmund, Barry Dock, Cardiff.
Kirkaldy, William, c/o Messrs. Wigham Richardson & Co., Neptune Works, Low Walker-on-Tyne.
Matheson, William, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne.
Phillips, John, 84, Blackfriars' Road, London, S.E.

Sharp, Mark, 144, Albert Road, Jarrow-on-Tyne.
Strong, George Aaron, West Percy Street, North Shields.
Thaw, Thomas, 8, Argyle Street, Newcastle-on-Tyne.

ASSOCIATES.

Bigge, C. W., Northern Counties' Club, Newcastle-on-Tyne.
Pirrie, Robert Reid, Guildhall Chambers, Quay, Newcastle-on-Tyne.

GRADUATES.

Blakey, John Henry, 5, Cambridge Street, Newcastle-on-Tyne.
Keen, Henry Bernard, 6, Beauclere Terrace, Sunderland.
Lander, John, c/o Messrs. Wigham Richardson & Co., Low Walker-on-Tyne.
Moffatt, James, 3, Lower Crescent, Belfast.
Nicholson, Philip Foster, Sandfield, West Boldon, near Sunderland.

DEPUTATION TO LLOYD'S.

The PRESIDENT reported that Mr. Price and himself waited upon Lloyd's Committee in London, together with certain representatives from the Clyde Shipbuilders, the Wear Shipbuilders, the Institution of Naval Architects, London, the Greenock Shipbuilders, the Tees and Hartlepool Shipbuilders' Association, and the Institution of Engineers and Shipbuilders of Glasgow. They were very courteously received by the committee. Mr. Ward, of Dumbarton, put the case very strongly from the Scotch point of view, and Mr. Price and himself had the honour of speaking on behalf of that Institution—each of them taking different phases of the bearing of the action of Lloyd's Committee upon the interests of shipbuilding, as they affected shipbuilders themselves and the public at large. Naturally, they could not expect an answer from them at the time, nor had they received one yet. The chairman simply expressed his gratification at having heard them and assured them that the committee would give the matter their most serious consideration. Shorthand notes were taken, and they were favoured with copies of them. He did not know that they were quite at liberty to make them public. He thought the matter was scarcely sufficiently advanced for them to deal with it at present, but he was quite sure that if they had heard the representations made to the committee they would have been satisfied that they had a very good case indeed.

MEDALS TO BE AWARDED.

The PRESIDENT then stated that he had a very pleasing piece of intelligence to communicate, and that was that the members of the Council had taken great interest in the raising of a fund for medals to be awarded for the best papers on naval architecture and engineering written during the session. They had succeeded so far, that two of their number in the Hartlepool district had contributed the very handsome sum between them of £274, to be funded, and the proceeds to be spent in purchasing two gold medals annually, one for naval architecture and the other for engineering. The making of the awards was to be left entirely in the hands of the Council, the members of which were exempted from sharing in the competition; and he thought he might further state that matters had progressed so far that a special medal would be provided of similar size and value for the Graduates of the Institution. The Council had not quite decided the matter yet. It was under consideration, and he thought the probability was that they should have a naval architecture medal and a marine engineering medal, and a medal for the Graduates of the Institution. They all owed a debt of gratitude to their Hartlepool friends for the steps they had taken in this matter, and he could only hope that it would induce some of the shipbuilders and owners on the other large rivers to take a similar step. They could very well dispose of scholarships and of awards for papers in this way in that Institution.

Mr. J. C. SPENCE read an Appendix to his paper on "The Strength of Boilers." The paper was then discussed, after which Mr. CHARLES B. CASEBOURNE read a paper on "The Construction of Marine Boilers with a view to the use of Higher Pressures."

APPENDIX.

THE STRENGTH OF BOILERS.

By J. C. SPENCE.

[Read before the Institution on December 16th, 1889.]

Having been requested to show by some practical examples, the application of the principles advocated in the paper which the author had the honour of reading at the last meeting, he has great pleasure in submitting to you the calculations for the two boilers, Figs. 10 and 11, Plate V., Fig. 10 being a boiler 15 feet diameter × 10 feet long, Fig. 11 being 10 feet diameter × 15 feet long, both of them being designed for a working pressure of 160 lbs.

In Fig. 9, Plate IV., A C E F, a rectangle 15 feet × 10 feet, represents a section through any diameter of either of these boilers, A C representing an end in Fig. 11 and a shell plate in Fig. 10, C E representing a shell plate in Fig. 11 and an end plate in Fig. 10. The argument given in the former paper was intended to show that the pressure in each of these two boilers produced a direct tension on this section, perpendicular to this plane, in each case equal to 15 feet × 10 feet × 144 × 160 lbs. = 3,456,000 lbs.; in each case the resultant of the pressure on all points of the boiler passes through G, the centre of this rectangle, and in each case the tension at any point of this section is independent of the form of the boiler, it depends only on the total strain and the distance of the point from G.

The curved diagram A K L M C, Fig. 9, Plate IV., represents the tension at each point of the line A C, and the curve C N O P E represents the tension at each point of the line C E. The scale of these tensions is shown at the margin of the diagram, from which it will be seen that—

The tension at D is about ...	8,200 lbs.	per inch of length.
„ „ C is	= 4,500 lbs.	„ „
The average tension along line E C	= 5,500 lbs.	„ „
„ „ „ A C	= 5,000 lbs.	„ „
The tension at C is	= 4,500 lbs.	„ „
„ „ B is	= 5,500 lbs.	„ „

Taking the tensile strength of plates at 12,500 lbs., and the strength through riveted joint at 10,000 lbs., and applying these figures to Fig. 10,

Plate V., we find that the shell plates should be made $\frac{1}{2}$ inch thick to stand a mean tension through joints of 5,000 lbs. At the ends these shell plates will be 10 per cent. thicker, and at the centre 10 per cent. thinner, than is required; but, considering that at the centre the plates are doubled for about 5 inches, giving double strength at the point where the greatest tension comes, the writer considers that $\frac{1}{2}$ inch plates would suffice. In any case, if the shell plates were made ·55 inch thick, they would be strong enough for the maximum strain.

Let us next consider the end plates of this boiler. For the back plate a uniform thickness of $\frac{3}{4}$ inch would be sufficient for a strain varying from 8,200 lbs. to 4,500 lbs., and having a mean value of 5,500 lbs., and as, for stiffness, we make the back plate $\frac{3}{4}$ inch or more in thickness, it is unnecessary to make any alterations in our present designs in order to carry this pressure. With regard to the front plate the question is much more complicated. The holes cut in this plate for the furnaces appear at first sight to be a great source of weakness, but the strength of the furnaces compensate in great part for this, and the pressure inside the boiler tending to collapse the furnaces balances, to a certain extent, the bursting pressure in the front plate in line of furnaces. Assuming that the pressure on the furnaces and the strength of the furnaces combined compensate entirely for the hole cut in furnace front plate, then we might use a $\frac{3}{4}$ inch plate for furnace front to correspond with the $\frac{3}{4}$ inch plate in boiler back. The top end plate is usually made of much greater thickness, to allow of the stays being widely pitched. If we make this plate $1\frac{1}{8}$ inches thick, we know that it will be sufficient for the tension we are now considering.

We now come to the tube plate. In this case the tubes, which are either screwed or expanded into tube plate, do not afford any support to the plate in compensation for the holes cut for them, and if it were necessary to make each part of the plate strong enough to support the strain on it, the tube plate where pierced for tubes would require to be $2\frac{1}{4}$ inches thick. If on the other hand it is considered sufficient to put in enough plate section to carry the total strain, then a $\frac{3}{4}$ inch plate, stiffened between the nests of tubes by doubling plates 1 inch thick, would give the plate section required. For the horizontal section of tube plate is weakest, being pierced by 31 holes; the vertical section is only pierced by 14 holes, and is stiffened by the thick top end plate, and any other section will be intermediate between these, so that it is only necessary to consider the horizontal section. If that is strong enough for its work, all other sections will be. The total strain on this is 1,140,480 lbs.,

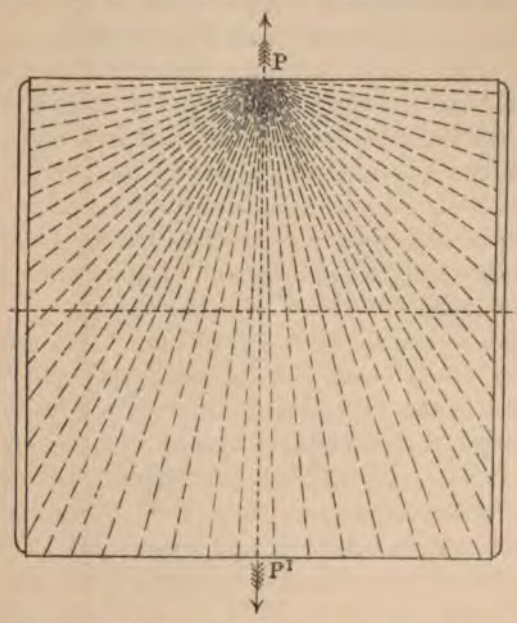
and requires a sectional area of 91 square inches. The length of the tube plate counting in the two flanges, which certainly ought to be counted, is 16 feet 4 inches = 196 inches; deducting the length cut away by 31 tubes $3\frac{1}{4}$ inches diameter, we have a length of 196 inches — $100\frac{3}{4}$ inches = $95\frac{1}{4}$ inches. If this is $\frac{3}{4}$ inch thick, we have a plate section of 71·4 inches, in the two doubling plates 10 inches × 1 inch we have another 20 inches of section, making a total of 91·4 square inches of plate section, the area required being 91. In the drawing the tube plate is shown $\frac{7}{8}$ inch thick, which gives a section of 103 square inches. If this is considered insufficient, under the circumstances, there could be no serious objection to making this plate 1 inch thick.

We now come to the boiler shown in Fig. 11, Plate V., and we will first consider the shell plates; the strain on them is represented by the diagram C N O P E. The tension on the two end courses varies from 4,500 lbs. at ends to about 7,250 lbs. where they join the centre course, with a mean of about 5,900 lbs., which corresponds to a thickness of plate of ·59 inch, in the drawing these plates are marked $\frac{5}{8}$ inch thick. On the centre course the tension varies from 8,200 lbs. at the centre to 7,250 lbs. at the junctions with end courses, the mean tension being about 7,700 lbs., corresponding to a thickness of ·77, this course is shown in drawing as $\frac{3}{4}$ inch thick.

The strain on end plates, represented by A K L M C, has an average of 5,000 lbs. per inch, or a total strain of 587,500 lbs., requiring a plate section of 47 square inches. The tube plate, if $\frac{3}{4}$ inch thick, pierced by 18 holes, $3\frac{1}{4}$ inches diameter, would give an area of $(136-58\frac{1}{2})$ $\frac{3}{4}$ = 58·9 square inches, 47 inches being all that is required. In this boiler the thickness of plates required would be as follows:—For centre course of shell plate, $\frac{3}{4}$ inch; for end courses of shell plates, $\frac{5}{8}$ inch; for top end plates, $1\frac{1}{8}$ inches (to suit pitch of stays); for furnace fronts and tube plates, $\frac{3}{4}$ inch.

The basis on which the whole of the foregoing arguments are founded is that the tension on any section of a vessel subject to internal pressure is independent of the form of the vessel, consequently the thickness of plates specified above would do equally well, so far as tension is concerned, if the vessel was made rectangular instead of circular in section, provided the flat top and sides were stayed sufficiently to form a practically rigid structure. We know that a rectangular boiler built of these scantlings could not stand a pressure of 160 lbs. per inch, unless it was stayed strongly, and we have now to enquire whether the circular boiler under consideration requires or could be strengthened by stays.

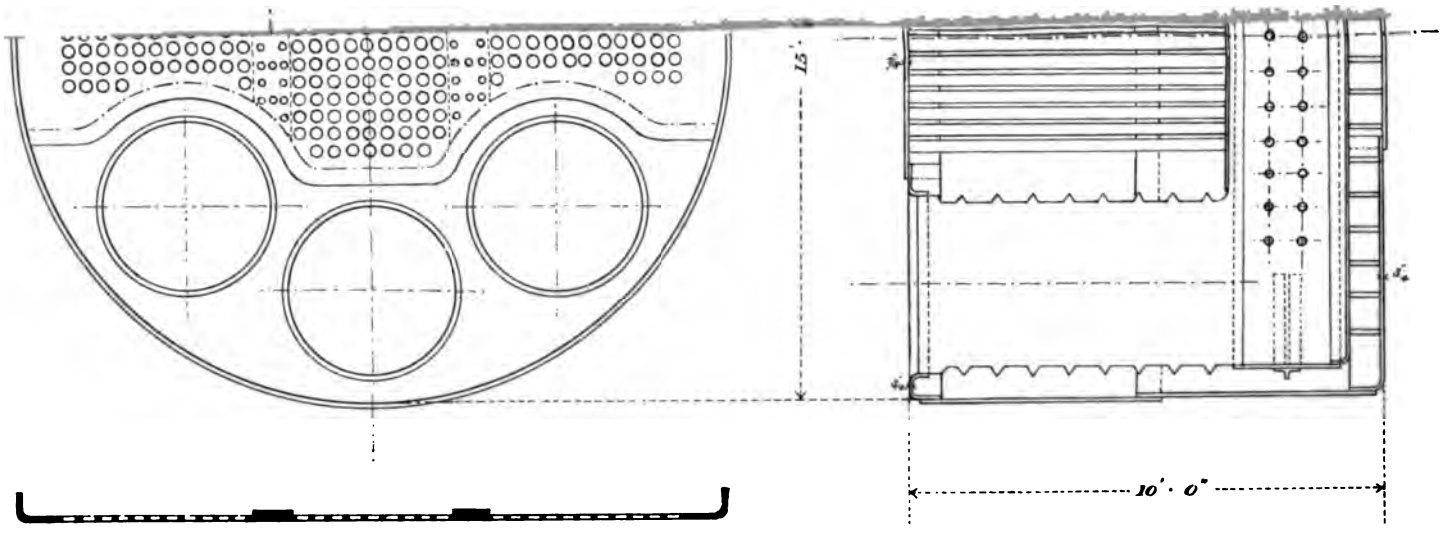
If we consider the boiler as composed of a series of disconnected rings, then clearly a shell plate, ½ inch thick, would not be sufficient for a boiler 15 feet diameter, at a pressure of 160 lbs.; or if we made a similar mistake and treated the boiler as if, like a barrel, it was composed of a series of disconnected staves placed side by side, then also each of these staves would bend under the pressure. But if we consider a boiler as a structural whole, no part of which can be strained from its normal position without bringing a strain in every other part of the structure, then we must conclude not only that these boilers require no staying, but also that they cannot be strengthened by stays. Of course, these remarks apply only to the circular shell and not to the flat ends.



Consider a pair of pressures applied at P and P′, two points opposite to each other in the shell of a cylindrical vessel, midway between the ends. The model before you probably shows this more clearly than the diagram. If the vessel were composed of a series of disconnected rings, the only effect of these pressures would be to stretch the ring which contained P P′, but if the vessel were made like a boiler in pieces, firmly secured together, then neither P nor P′ can move without stretching every line connecting either of these points to each point in the two ends. It is impossible for the ends to receive any part of the strain on P without reducing to a corresponding extent the strain on the ring, and, consequently, the tension on each ring in a boiler is very much less than we estimate when we take no account of the ends, and the strain in any narrow section of the boiler is not the whole strain due to the pressure within that section, but only that part of it which is not tending to stretch the end plates. If, then, the ends of a boiler in any case carry two-thirds of the total bursting pressure, only one-third of that total can

To illustrate Appendix to Mr. J. C. Spence's Paper on the Strength of Boilers.

FIG. 11.



come upon the ring of shell, and a shell plate made to carry one-third of the total pressure would be strong enough, would require no staying, and could not be strengthened by stays.

Again, if this vessel were made of disconnected staves the pressures at P and P′ would bend the two staves A A and B B both outward from the centre, but being connected rigidly together, the pressure at P tends to bend the vessel as a whole upward, while the pressure at P′ tends to bend the vessel as a whole downwards, the two moments of flexure about the neutral axis, being exactly equal and opposite, cancel one another. If we neglect the weight of water in a boiler, which makes the pressure on the bottom rather greater than the pressure on the top, then as every point in a cylinder has a point opposite to it at which the pressure is equal, the bending moment due to the pressure at any point is balanced by the bending moment due to the pressure at the opposite point.

The PRESIDENT—There is one thing I would like to be perfectly clear about: do you calculate, for the purpose of your argument, the whole pressure upon this point?

Mr. SPENCE—By no means.

The PRESIDENT—You say, "Consider a pair of pressures concentrated here."

Mr. SPENCE—Just so; I take this square inch in the centre of the shell and suppose it has a pressure of 160 lbs. on it tending to bend the whole boiler as a beam upward, then I say there is a point exactly opposite this subject to an equal pressure but in the opposite direction, and these two movements cancel each other.

The PRESIDENT—I rather gathered that you said that the whole strain from here to here was concentrated at this point. I gather from you that that is not so?

Mr. SPENCE—Well, they are both my meaning; I don't think they are inconsistent.

The PRESIDENT—Is it a uniformly loaded girder, or one loaded in the centre?

Mr. SPENCE—So far as that is concerned, if we consider the deflection on this strip of plate, it makes a difference of 2 to 1 whether we consider the load concentrated at the centre or distributed equally along the strip. But if we are considering the strain on the supports of this strip it makes no difference whether the load is distributed or concentrated. What I said in the former paper referred to the strain on the supports of the shell, not to the rigidity of the shell.

The PRESIDENT—It materially affects the condition of the thing. I am satisfied.

From these arguments the writer concludes that the thickness of shell plates in marine boilers could be greatly reduced without making any reduction in our factors of safety, and without any important alteration in our designs; that the thicknesses specified above are sufficient to resist the bursting pressure on the boilers, treated as structural units, and that they are sufficient to meet all local strains. That each cross section of the boiler, treated not as a disconnected ring, but as rigidly connected to every other part of the boiler, will be found strong enough for the work it has to do, and that each longitudinal section in the shell, treated not as a disconnected stave, but as rigidly connected to every other part of the boiler, will also be strong enough for its work.

DISCUSSION.

The PRESIDENT said, the subject was now before them. He sincerely regretted that they had not both papers read at the same time; it would have been a little more easy to follow. The discussion would now proceed.

The SECRETARY (Mr. J. Duckitt) intimated that he had a communication from Mr. Stirzaker.

The PRESIDENT having put it to the meeting, it was agreed that it should be read.

COMMUNICATION FROM MR. STIRZAKER.

December 13*th*, 1889.

DEAR MR. DUCKITT,—I had intended to take part in the discussion of Mr. Spence's paper on Monday evening, but now find I shall require to be in the South of England on that day. No doubt the error into which Mr. Spence has fallen will be clearly demonstrated at the meeting. That error is, the assuming that a fluid pressure may be treated in the same manner as the pressure of a solid. The pressure of a solid body may be overcome by applying a force at the centre of gravity of that body; but a fluid pressure acts equally in all directions, and the centre of pressure is a mathematical expression rather than an actual position, and whatever force is applied at that point must be distributed mechanically over the *area* of pressure. Mr. Spence tacitly acknowledges this fact by the manner in which he has drawn the lid of the box in Fig. 3, Plate III., making it the shape of a beam which has to bear a distributed load, and yet he proceeds to say that this "lid might be altered to any shape we pleased." How, if we pleased to make it flat and of a uniform

thickness? Would it not then tend to bulge in the centre, where the bending moment, due to a fluid, or a distributed pressure, is greatest?

This is just what happened to the experimental boiler made and tested by Mr. Scott. This experiment Mr. Spence advances as an insurmountable proof that the present method of calculating the strength of a boiler is erroneous and his own correct. But, if we investigate the stresses which came upon that boiler when under test, we shall find that Mr. Spence's deductions are not warranted. Take the conditions of the boiler when under the test of 580 lbs. per square inch. It is more convenient to deal with that experiment than with the later one of 620 lbs. because the circumferential seams were not distorted, as they afterwards became, thereby complicating the calculation. Treating only of the centre ring of plates, because these are the least influenced by the ends of the boiler, we find that after being tested they took a bulge, or a permanent set, at the centre, of $1\frac{1}{16}$ of an inch. This represents a permanent set of ·0115 of an inch per inch in the length of the plate. From some experiments with which I was connected made upon mild steel, having an ultimate tensional strength of $28\frac{1}{2}$ tons and an elongation of $27\frac{1}{4}$ per cent. in a length of 8 inches, with an elastic limit of 15 tons per square inch, I found that a permanent set of ·0115 per inch took place when the load was $16\frac{1}{4}$ tons, or $1\frac{1}{4}$ tons above the elastic limit of the material. I also found that the *total* extension of the material (that is the elastic extension, plus the inelastic extension, or permanent set) was ·013 per inch. Now, the elastic limit of the steel in Scott's boiler was $16\frac{1}{2}$ tons. Adding $1\frac{1}{4}$ tons to this gives us $17\frac{3}{4}$ tons as being the stress upon the centre plates of Scott's boiler when under a pressure of 580 lbs. per square inch.

Let us now calculate the pressure which this portion of the boiler would carry with a stress of $17\frac{3}{4}$ tons per square inch.

1st.—Treating the ring simply as a plain cylinder, the diameter being 92 inches and the thickness of the plates $\frac{19}{32}$ of an inch, we have—

$$p = \frac{2\,t.f. \times 2{,}240}{D}$$

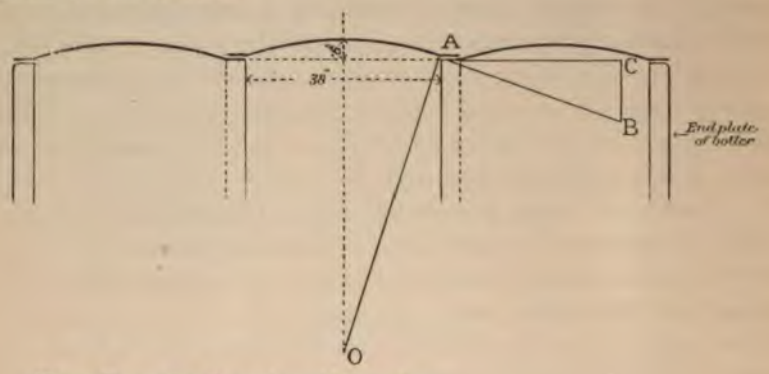
$$= \frac{4{,}480 \times \frac{19}{32} \times 17{\cdot}75}{92}$$

$$= 513 \text{ lbs. per square inch.}$$

But the centre ring is not a plain cylinder. It has become partially spherical. Let us then see what is the additional strength it has obtained by taking this form.

First, find the radius of the curvature of the plate.

The cord of this curve is about 38 inches, and the increase of diameter at the centre is 92 × ·013 = 1·196 inches, practically 1·2 inches. Therefore the versed sine of the chord equals ·6 of an inch, as shown, exaggerated, in the sketch.



Now, D, or the diameter of the sphere,

$$= \frac{(\frac{1}{2}\text{ chord})^2}{\text{versed sine}} + \text{versed sine},$$

$$\text{therefore } D = \frac{19^2}{\cdot 6} + \cdot 6 = 602 \text{ inches diameter.}$$

We have, therefore, secondly, a new cylinder to deal with, 602 inches diameter, the material of which is strained in a different direction to that of the former one.

The strength of this cylinder will be—

$$p = \frac{4{,}480 \times \frac{19}{32} \times 17{\cdot}75}{602} = 77 \text{ lbs. per square inch.}$$

Therefore the total strength of the boiler at the centre ring of plates is 513 + 77 = 590 lbs. per square inch, as against the 580 lbs. obtained by actual test.

I have dealt with this calculation as if the plate were solid, neglecting the riveted joints. I do not think, however, that the riveted joints will materially alter the result. Theoretically, they are 84 per cent. of the strength of the solid plate, therefore, *also theoretically*, they would be strained to $\frac{17{\cdot}74}{84}$ or 21·13 tons per square inch—not an utterly impossible stress for them to take.

But I do not for a moment suppose that the 84 per cent. of the theoretical strength of the joints is the actual percentage of strength. It might be so if treating only of a unit length of riveted joint, though even then the friction caused by the grip of the butt straps on the shell

plates would probably have some considerable value, but here, where the line of the shell plate joints is broken, the joint is supported at both ends with a solid plate.

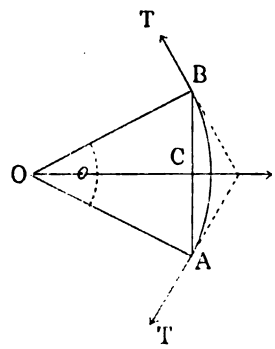
The stress set up in the circumferential seams, by the bulging of the plates, can be obtained thus:—Through the joint of the plate at A draw A B, making it tangential to the curve of the plate at this point. Let A B represent the tensional stress on the plate. Then, triangulating the forces, acting at the point A, in in the usual way, A C will represent the longitudinal tension at the seam, and B C the additional outward or bursting pressure upon it.

In treating of the ultimate test of the boiler with a pressure of 620 lbs. per square inch, we should probably be fairly accurate, if we considered the further stress on the material to be in proportion to the pressures. This would give—

$$17{\cdot}75 \times \frac{620}{580} = 19 \text{ tons per square inch.}$$

If I have succeeded in showing that the ordinary method of calculating the strength of a structure is capable of accounting for the results obtained with Mr. Scott's boiler, then that experiment goes to prove the accuracy of the present method of obtaining the strength of a boiler, and, consequently, the incorrectness of that proposed by Mr. Spence. A boiler intended to be cylindrical, will not give satisfaction, if, under pressure it changes form, but if we desire to make a boiler of great strength, relatively to its weight, we might do worse than adopt the form which Mr. Scott's boiler put itself into, by rolling the plates slightly spherical, and making the circumferential seams sufficiently strong to withstand the additional stress upon them.

J. C. STIRZAKER.



Mr. J. T. MILTON said, it appeared to him that Mr. Spence had assumed that what he called the old theory required a complete cylinder for its proof; that is not so. The theory is perfectly true if we only take a small part of the cylindrical shell, provided it is supported at the ends by tangential forces only. For instance, let A B be the transverse section of a part of the cylinder, then if A B subtends an angle θ at the centre of the cylinder, and if p be the intensity of the internal pressure, we have the portion A B in equilibrium under a force equal to the pressure on A B,

i.e., $= p \times \text{A B}$, and the two forces T, T acting tangentially at A and B, called into play by the strength of the materials. (From symmetry we see that the forces T, T are equal.) Since there is equilibrium we have, by resolving the forces parallel to O C—

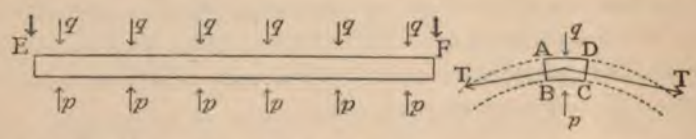
$$p \cdot \text{A B} = 2\text{T} \sin \frac{\theta}{2}.$$

Now, $$\sin \frac{\theta}{2} = \frac{\text{B C}}{\text{O B}} = \frac{\text{A B}}{2 \times \text{radius}},$$

hence $\text{T} = p \times$ radius, which is the result Mr. Spence obtains by considering the equilibrium of a semicircle instead of that of *any* part of the cylinder. This proof holds good whatever be the angle B O A, and therefore must be true when this angle is very small. It is easily seen that the converse to the theory holds true, viz., that a tension T in the shell will equilibrate or balance an internal pressure of—

$$\frac{\text{T}}{\text{radius}}.$$

Now, let us consider the case of an actual boiler shell subjected to a uniform internal pressure p. If there is equilibrium, we know that if we take *any* special part of the shell, the forces acting on that special part of the shell must all be balanced; that is, the internal pressure acting on the area of the part under consideration must balance with the forces brought into play by the strength of the material around the periphery of the portion. Take, for instance, a longitudinal slice of the boiler shell,



say one inch wide, and let A B C D be the cross section of the piece E F the side elevation of it, E and F being the points of the attachment to the ends. This piece, then, is in equilibrium under the internal pressure p applied on the area $\text{B C} \times \text{E F}$, and the support it gets from its connection with the rest of the boiler; that is, some tangential forces T T on both sides of the strip along its whole length, and also the forces E and F at the extreme ends, where E and F are the supports actually given by the ends. Now, according to Mr. Spence's theory, these forces E and F are of considerable magnitude, while according to the old theory they are so small that they may be neglected as being inappreciable. Whatever be the magnitude of the forces T—, · · · (that is, whatever be the actual circum-

ferential tension on the boiler shell at any point of the length of the boiler) its effect is, as has been shown, to balance an internal pressure—

$$q = \frac{\text{T}}{\text{radius}},$$

at that point. We may therefore replace the tensions T, T acting along the longitudinal sections by their resultants, q, q, q, acting radially along the strip (q, q · · · are not uniform unless the circumferential tensions T, T · · · are uniform along the length of the boiler). The strip, of which A B C D is a cross section, is therefore practically a bar supported at E and F, and acted on along its length by pressures $p-q$, · · · . Now if these pressures $p-q$ · · · have any appreciable magnitude, they must produce a considerable deflection unless E F is very short. But we know as a fact that the distortion is very small in practice, hence we can only conclude that, except in the case of a very short shell like that quoted by Mr. Spence as being 6 inches long, $p-q$ cannot have, at any part of the length, any appreciable magnitude, so that practically $p = q$, and consequently the tension on the plate per unit length is $p \times r$, which is that given by the old theory. It is worth noting that in a beam, such as we are considering, the deflection varies as the *cube* of the length, so that the support got from the ends of shell 1 foot long is practically only $\frac{1}{8}$th that in the case of one 6 inches long with the same amount of deflection. In 2 feet length it will be $\frac{1}{64}$th, and so on.

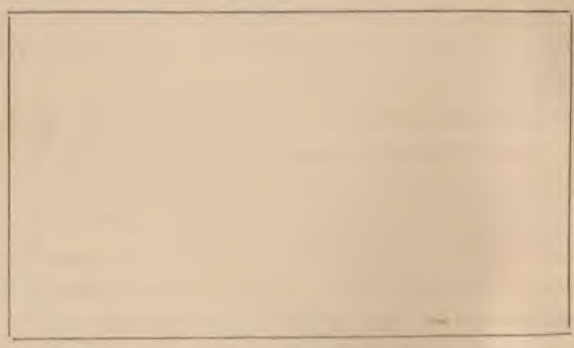
Mr. Spence in his numerical calculations had, he thought, gone adrift too. In the first paper he (Mr. Milton) thought he had only provided for the *mean* strain along the whole side. That evening he somewhat modified that by putting the thicker plates in the middle.

Mr. Spence—This stress diagram is the same as in the paper.

Mr. Milton—Mr. Spence in his paper gave them total strains, that was practically equivalent to mean strains. He had taken the pains to investigate how the maximum stress came out on what we may call the inverse theory. According to that theory, in Mr. Scott's boiler the maximum strain turned out to be 1·35 times the mean strain, and the thickness of the plates must be made to bear the *maximum*, not the *mean* stress. Mr. Spence again, he thought, had misread all Mr. Scott's experiments. As he (Mr. Milton) read Mr. Scott's experiments in the *Transactions of the Institution of Naval Architects*, the pressure of 450 lbs. per square inch was that which brought the limit of elasticity on the plates. In Table 4, of that paper he thought, Mr. Scott gave the amount of permanent set at 450 lbs. per square inch, so evidently 450 lbs. per square inch was at least equal to the pressure which produced the limit of elasticity on the solid

plate. If they applied the ordinary theory to Scott's boiler, they had at this pressure, a stress of 15·6 tons per square inch, which was nearly what Mr. Scott regarded as the elastic strain, viz., about 16 tons per square inch. For the theory that the strain varies inversely to the distance he could not see any ground whatever. If there were only two forces, supported by another in the straight line joining them, the rule was true; but whenever they got three or more forces having one resultant, the magnitudes of these forces did not accord with Mr. Spence's theory.

Mr. B. G. NICHOL said they had for many years been struggling to make boilers as light as they possibly could be, and yet be sufficiently strong for the work called upon them to sustain. The question before them, he thought, was whether the rules on which they had been working for years past—rules agreed to by Lloyd's and the Board of Trade—were wrong? They had before them the theory which Mr. Spence had put down. He must say that, looking at it without taking the trouble to go all through Mr. Spence's calculations, he fancied there was a good deal in the paper Mr. Spence had read. He would take a piece of chalk and try to prove it.



As far as he could gather from the rules of Lloyd's and the Board of Trade, the principle adopted was equivalent to flattening the shell plate, firmly fixing it along the edges, and regarding the whole flat plate as a bridge uniformly loaded, and in such case it must be perfectly plain to everyone that no account was taken of the ends. He could not himself conceive that those end plates had not some amount of value. If we take this model of Mr. Spence's, representing an ordinary boiler shell, 10 feet diameter by 10 feet long, cut it through the middle, and place the top half at an angle of 90 degs. to the bottom half, how in the name of wonder could they say that the flat ends of the lower half had not an effect in

holding the whole structure together? The ends must assuredly have some influence. He (Mr. Nichol) had not seen anything in the arguments adduced that the methods Mr. Spence adopted of measuring the strain on end and circumference was incorrect. Supposing they had a boiler 10 feet diameter and 10 feet long, they had an area of about 78 square feet at each end, and the pressure being uniform they had it applied on 156 square feet at the ends as compared with $10 \times 10 = 100$ square feet tending to produce barrelling. So long as the end pressure was greater than they had on the circumference, he could not see where they were going to have the shell assume the barrel form. If they were going to make it 20 or 30 feet long, the pressure on the ends would be small compared to that on the shell itself; but, even then, the ends must be of some distinct value. He was of opinion that the analysis of Scott's experiments conclusively proved that Mr. Spence had got hold of data which thoroughly supported his contention.

Mr. R. L. Weighton thought that most of them would be agreed there was a great mistake in this paper, and it seemed to him that the mistake was of a very fundamental character. Mr. Spence's theory rested upon a pure fallacy, and the fallacy occurred first of all in the very beginning of the paper, where Mr. Spence, in order to prove his theory, dealt with the forces acting inside of a boiler in a quite illegitimate way. He converted a distributed force into a concentrated one, tacitly assuming that the strains acting inside a boiler on its boundary walls would not be affected thereby if you conceive of those strains tending to rupture the boiler through any section. He (Mr. Weighton) considered that an entire fallacy. It was true enough as regarded motion through space. If they cut this model of a boiler through, say, a horizontal plane, they might say, in regard to motion of the upper half through space, that the moving force may be conceived as acting at the centre of gravity of the section, without altering in any way the direction of motion or its amount; but as regarded molecular strain in the material of the boundary walls of the boiler, the concentration of all the forces at the centre of gravity entirely altered the conditions. The only condition under which that would be even conceivably true would be if the material was infinitely rigid, or at least so rigid as to perfectly preserve its *form* when the previously distributed forces were concentrated and collected at one point, viz., the centre of gravity. But *if* the material *were* of this almost infinite rigidity, then they could not proceed to do as Mr. Spence proceeded to do, viz., to distribute the forces to the outside, and say the boundary walls are strained in inverse proportion to the distance from

the centre. In order that this might be true they must assume the material to have almost infinite elasticity. It would require to be composed of a series of separate and detached wires, so to speak. If it had infinite rigidity, and the forces were all concentrated upon any point, it would transmit the stresses *uniformly* all round the shell and ends of the boiler, for the material, being rigid, did not move upon itself—no part can give way or stretch before another part; but if the stress at one part of the shell was more than at another, the material must move upon itself—it must stretch at some parts and not at others. This he conceived to be a fundamental fallacy, and after that he did not know it was necessary to say more. For one purpose Mr. Spence assumes the material of boilers to be of almost infinite rigidity, and for another purpose he assumes it to be of almost infinite elasticity. All this deals with the theoretical part of the subject, and did not appeal to engineers with the same force as it otherwise might do. He would therefore refer to the practical example of the boiler tested by Mr. Scott, of Greenock Foundry, which, no less than the theoretical part of the question, seemed to him (Mr. Weighton) to condemn Mr. Spence's reasoning. Mr. Spence, referring to Mr. Scott's boiler, says:—"When the pressure was reduced it was found that it had produced no fracture, and no serious disturbance of the structure, proving that the elastic limit had not been greatly exceeded, for had the strain approached the breaking strain of the material they would have seen a very serious disturbance of the structure; the experimenters would have seen it swelling visibly before their eyes." And again:—"This boiler, which all the evidence proves to have been strained just above its elastic limit." Further down he referred to an experiment by Mr. Manuel, brought forward at the meeting of Naval Architects, at which this question was discussed. That joint was simply the ordinary chain riveted joint, a series of them had been tested, and the extensions and breaking strain noted. This was the point he (Mr. Weighton) wanted specially to emphasise, and show by applying the results of Mr. Manuel's joint that this boiler behaved exactly as it would have been expected to do on the accepted theory of calculation. The joint Mr. Manuel brought forward broke at 28·7 tons, and the extension is given at various stages below the breaking point. Now, at 93 per cent. of the ultimate strength, which was the point to which Mr. Scott's boiler was strained through the rivet holes, Mr. Manuel's joint gives an extension of about 1·1 per cent. Mr. Scott's boiler swelled permanently in diameter to the extent of $1\frac{5}{16}$ inches under the same degree of stress, and this is equal to about 1·4 per cent. So this boiler extended more than

Mr. Manuel's joint under the same conditions of stress. How could Mr. Spence say that the elastic limit had not been greatly exceeded? If the elastic limit was not greatly exceeded, whence this great permanent extension of the material, equal to $4\frac{1}{8}$ inches in the circumference of the boiler, and equal to more than the stretching of a riveted joint which is strained to within 93 per cent. of its breaking point? With regard to the model shown, it illustrated the matter more graphically than the diagrams; but Mr. Spence was under a peculiar misapprehension. He said the stresses were transmitted to the ends through powerful girders. But these stresses would have a resultant longitudinally, and that resultant acted so as to pull the outer edges of the ends in, and the central parts of the ends had a tendency to bulge out in every case. In a word, the tendency of the forces acting inside an ordinary cylindrical boiler was to render the shape of the boiler spherical, and when the true sphere is reached the stresses on the material are of course less than in the case of a cylinder. They did not get any help from the ends at all till the boiler shell bulged, and then they were past the point at which the boiler was useful. They needed to consider two points: the bursting point and the testing point. If they took account of the *bursting* only of the boiler, the ends would have the effect of raising the bursting point; that was, a boiler with ends riveted into it would take more to burst it than a boiler with mere stuffing boxes as ends; but before—long before—they came to the bursting point, the boiler was useless for all practical purposes, and so they had only to deal with some stress much below the elastic limit even, viz.: the test stress, and at this stress the ends could have no effect, because the middle would not be bulged, and on that ground he did not think the theory which takes account of the ends worthy of practical consideration.

Mr. J. Jennings Campbell said he had not been present at the Sunderland meeting, and had not seen all the diagrams, as some had not been put up for the discussion, but he thought that the point raised by Mr. Weighton might be more clearly shown from Fig. 6, Plate III., in which Mr. Spence had taken the case of a box lid held down by bolts all round. Here, with an area of 15 inches $\times$ 10 inches $=$ 150 square inches, and with a pressure of 100 lbs. per square inch there is a total pressure of 15,000 lbs. Mr. Spence stated that this might be taken as all being concentrated at the centre of the cover as in the case of a loaded safety valve, but this would only be the case when the cover or lid was assumed to be perfectly rigid, and in that case the bolts would all have the same strain, whether near to or far from the centre of gravity. This was where the author had gone wrong in his theory.

Mr. ALEXANDER TAYLOR said, that when in Greenock he had taken advantage of Mr. Scott's offer and saw the boiler which had been made and tested by the Greenock Foundry Co. The plates were barrelled as shown in sketch given on page 78. In his paper, Mr. Scott says:—"The experiment which this paper has endeavoured to describe seem to present *some justification for a reduction in the minimum scantlings of the shells* in marine boilers of merchant service to at least the scale now adopted by the Admiralty." The boiler was made for a working pressure of 145 lbs. according to Admiralty practice, and 135 lbs. according to Lloyd's rules. After Mr. Scott read his paper, he added as follows:—"You will perhaps allow me to offer one observation in extension of this paper which occurred to me after I sent in the manuscript for printing. It is this, that an examination of the tube shows the extensions that have taken place in the various tubes of the three rings of the boiler, which are extremely marked. Any one who is good enough to visit the boiler, I shall be extremely happy to show it to. Each of the streaks of the plates—one, two, and three, as marked in the drawing—has assumed a barrel form, the ordinates of which you will find in the table. I shall wish to express in continuation of the paper that that examination of the manner in which extension may take place under extreme pressure may possibly form a *good reason for the reduction of the breadth of the plating now being so much used* by engineers in the construction of their boilers, as it is well known to all marine engineers here present that in constructing double-ended boilers of large length, probably up to nearly 18 feet, it is a common practice at present to use plates up to 6 feet in breadth. The result of this experiment may show that in doing so engineers are extending the limit of safety in that direction a little too far. It is evident from the experiment made here that lines of strength are formed by the circumferential seams of the plates, and it may be the case that the ultimate width to which plates may with safety be extended, require consideration on the part of those who are designing boilers." Now, I would ask if Mr. Scott reduce the breadth of the shell plates and increase the number of courses, does he not also increase the number of stiffening rings, and thereby increase the factor of safety, so that while he wishes on one hand to reduce the factor of safety, on the other hand he wishes to increase it? Mr. Spence says this boiler bore out his theory. Now, according to the ordinary mode of calculation, when the pressure was 620 lbs. per square inch, the material would be under a stress of 21½ tons, but, according to Mr. Spence's calculations, at 620 lbs. pressure the material would only be under a stress of 13½

tons, and as this is considerably under the elastic limit, perhaps Mr. Spence will explain why the plate bulges as described by Mr. Scott.

Mr. SPENCE—That pressure is on the plate, it is not on the joints; I have it in my paper $16\frac{1}{2}$ tons.

Mr. TAYLOR—That is so, $16\frac{1}{2}$ tons on the joint. But I am taking the stress on the solid plate in each case, and the solid plate has only a stress of $13\frac{1}{2}$ tons. Why, with only $13\frac{1}{2}$ tons per square inch upon the plate should they take a permanent set in various courses from $1\frac{1}{4}$ inches to $1\frac{13}{16}$ inches?

MR. SPENCE'S REPLY TO THE DISCUSSION ON "THE STRENGTH OF BOILERS."

Mr. J. C. SPENCE in reply said, before bringing forward such startling proposals as those contained in the paper under discussion, the writer had tried his utmost to find any weak spot in his arguments, but had failed to do so. The discussion had convinced him that while the main principles brought forward by him were not only true but indisputable, yet there was one point he had taken for granted, which is, he would not say wrong, but open to doubt and to modification. The principles which he contended were absolutely true were these:—1st, that the method now in use of treating short boilers of the marine type as endless rings, is radically wrong, and involves an error of unknown magnitude, varying with every proportion of length to diameter. 2nd, that instead of taking arbitrary sections through a boiler, we should consider such sections as pressure within the boiler tends to produce, that is, we should take a central section through shell and ends, and having determined what pressure comes upon the ends, and what on the shell, we should design our boilers to stand these strains.

The principle—that he admitted was open to doubt—was a matter of very small importance compared with the foregoing; it was, that the strain on each point of a section varied exactly in the inverse proportion of its distance from the centre.

To the first of these propositions there was no reply. In his paper he had stated that the formulæ now in use are deduced from the theory of open rings by "good and sufficient reasons," he had then given arguments and examples to prove, that the open ring theory was not applicable to marine boilers. Mr. Milton courteously assuming that the writer was ignorant of these good and sufficient reasons, kindly supplied them, and proved what is not disputed, that the formulæ in present use are but particular cases of the general theory of rings strained by internal pressure. This is not to discuss the question at issue, but to evade it.

Again, in his paper he had brought forward arguments, illustrations, and models to prove that a longitudinal strip, if treated as cut out from the rest of the boiler, that is, as a beam supported at its two ends, does not represent the same strip when forming an integral portion of the boiler—it does not represent it exactly, nor even approximately. The strength in the one case bears absolutely no relation to the strength in the other case. Mr. Milton coolly ignores this argument, and proceeds to investigate the resistance of a longitudinal strip an inch wide, supported at the two ends; and of course, he finds that such a strip can not afford much support to the rings, and that this support varies inversely as the cube of its length. Is it possible that he can fail to see that the question raised, is not, what is the strength of a disconnected stave, such as he deals with, but whether the strength of such a strip bears any relation whatever to the strength of the same strip when forming part of a huge beam, and balanced by an exactly equal, but opposite, moment of flexure produced by the strip opposite to it in that beam?

As no other speaker had attempted to answer his arguments on this point, he would pass on to the next, which is illustrated by Figs. 3, 4, 5, and 6, Plate III. This involves a simple mechanical principle as nearly axiomatic as any he knew in engineering. Mr. Nichol's illustration of this principle, given in the discussion, was much more striking and appropriate than the author's, as the example was such as might occur in an actual boiler, and the strain was transmitted direct from one plate to another without bolts or flanges. But although the figures given in his paper did not represent boilers, they serve perfectly to illustrate this principle. Leaving for after consideration the question whether the strain on the bolts in Fig. 6, Plate III., varies as shown there, the fact that he wanted them to note was that the strain on the bolts was precisely the same whatever shape the lid was made.

Mr. Stirzaker's reply to this argument is simply absurd. He does not attempt to argue that the strain would differ in either of the three examples quoted, nor to estimate what the difference would be. But he says that the theory (that the strain is equal in all cases) "involves the error of treating a fluid pressure in the same manner as the pressure of a solid, and treating a centre of pressure as having an actual position, while it is rather a mathematical expression." Now the pressure of 1 lb., whether caused by the weight of a solid, by a head of liquid, or by the elasticity of a gas, remains 1 lb. pressure—it is neither more nor less, nor different. And a centre of pressure which has not an actual position is an impossibility. Although his mode of expression is unintelligible, it may be gathered from the context, that his meaning is, that a

distributed pressure is not identical with a concentrated pressure, and that if the pressure on the lid of this box is balanced by a single load applied at the centre, the load must be applied to the lid, and not directly to the fluid inside. Both of these propositions are true, but have nothing to do with the question.

In his (Mr. Spence's) statement of the case, he had said that the lid might be made of any form we please, and the strain on the bolts would remain the same. To this Mr. Stirzaker replies, How if we make the lid a thin flat plate; would it not bulge in the centre? Only noting, that this is to alter, not the form of the lid but its strength, he would answer. Let it bulge, so long as it does not break and let the pressure and the problem escape us; and when it had done bulging, he would ask Mr. Stirzaker whether the strain on the bolts was altered by the bulging of the plate? In his argument he would have been perfectly justified in assuming the lids were in all cases rigid bodies, for although there is no substance in nature which is a rigid body, yet the assumption is constantly made, whenever we wish to eliminate from a problem, the alteration of form in a body transmitting a strain, and to confine our attention to the strains transmitted; he had not made this assumption solely because, in this particular case, it does not matter in the least whether the lid is rigid or not.

Mr. Weighton's argument betrays the same confusion of thought, with regard to two perfectly distinct problems, as the argument we have just examined. Mr. Weighton accused him of converting a distributed force into a concentrated one, but this charge was made without the smallest foundation. Mr. Weighton can not possibly call in question the fact that the vertical component of pressure on any surface whatever is the same as that of a vertical pressure on the plane area forming the horizontal projection of that surface. This is true in all cases, and does not depend on the form or dimensions of the surface, nor on the material of which that surface is composed. He can not deny that the resultant of a distributed pressure on a plane area is a single pressure passing through the centre of gravity of that area. If he admits these axioms, he must admit that the strain on the bolts in Fig. 6, Plate III., and the strain on the plate section in Figs. 9 and 10, Plates IV. and V., is independent of the form of surface, and is the same as that produced by a single pressure at the centre of each of these rectangles. If he admits these axiomatic truths his argument becomes meaningless. If he denies them, it is necessarily erroneous.

In discussing a complex problem it is perfectly legitimate to discuss one point at a time, it is usually the only possible method—it is the

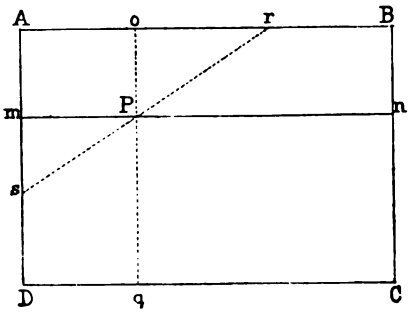
method used in his paper. In the first place he had tried to determine how the resultant pressure on a boiler shell was distributed between the shell and the ends. And to do this, he entirely ignored the effect the pressure might have in altering the shape of the shell, and confined his attention solely to the resultant strain brought upon a particular section. But, having found by this means, how the tension is distributed over the section, he then used a different process of argument to show that if the shell plates were strong enough to stand the tension that came upon them, then they were strong enough for all purposes. This method is most certainly not what Mr. Weighton describes it, a conversion of a distributed pressure into a concentrated one.

Having experienced how easy it is to be misunderstood, he did not feel at all certain that he had grasped Mr. Weighton's meaning in the next argument, which appears to convert a statical problem of pressure and tension into a dynamical one of motion through space, and introduces several phrases new to mechanics, such as infinite rigidity and infinite elasticity. But, so far as he could make out Mr. Weighton's meaning, it was, that treating the problem by the method of virtual velocities, the new theory was correct. But then, he proceeds to say that this involves two entirely contradictory suppositions with regard to the material of which a boiler is constructed, at one stage infinite elasticity, at another, infinite rigidity. Now, if we are to understand by, infinite, the same thing as is often spoken of in applied mechanics as, perfect, elasticity and rigidity, then there was nothing contradictory in assuming the one property at one stage of an argument, and the other, at another stage. He found this definition of rigidity in *Todhunter's Analytical Statics*. "A rigid body is one in which the particles retain invariable positions with respect to each other. No body in nature is perfectly rigid, every body yields more or less to the forces that act on it. If, then, in any case this compressibility is of a sensible magnitude, we shall suppose that the body has assumed its figure of equilibrium, and then consider the points of application of the forces as a system of invariable form." Again, by a perfectly elastic body is meant, a body in which extension varies directly as tension, or generally, stress varies as strain. And, up to the pressures we use in boilers, steel is a perfectly elastic body. It is therefore a perfectly legitimate process of reasoning to treat a boiler as a rigid body when once it has been stretched under the influence of a given pressure, so long as that pressure remains constant, the boiler acts in every way as a perfectly rigid body. And, on the other hand, if we wish to find how much it will stretch, we assume the material to be perfectly elastic, an

assumption that is practically exact. Mr. Weighton's argument about rigidity and elasticity is therefore absolutely worthless. It is not only worthless, it is also quite irrelevant. The theory he is discussing is a perfectly general law, applicable to every solid body capable of resisting pressure and tension in any degree, and absolutely independent of any abstract theories about rigidity or elasticity. The only value, if any, his argument has, is, that he shows the new theory true by the method of "virtual velocities."

We now come to the point which he had admitted was open to doubt. Mr. Campbell had said that the author "had gone wrong by not assuming that the lid in Fig. 6, Plate III., was perfectly rigid, in which case the strain would be equally divided between all the bolts." When he admitted that the first rough draft of his paper had been written on this assumption, he must admit that there was some force in this argument. Although he did not consider this theory as exact, he had thought the error involved was so small that it might be covered by the large factor of safety used in boiler work. The difference between assuming that the strain is equally distributed along shell and ends, or distributed in the manner assumed, is very small compared with the difference between either of these assumptions and the assumption that the strain is wholly concentrated on shell plates; but still it is a difference worth considering. His reasons for adopting the theory of inverse proportions were not based on any abstract theories of rigidity or elasticity, but on the well-known properties of the lever.

Mr. Milton says that "if there are two forces supporting another in the same straight line, that these two forces vary inversely as their distance from the third; but whenever we get three or more forces having one resultant the magnitude of these forces does not accord with this theory." This is true in one sense, but very far from the truth in another. Give an engineer the relation between three forces and he will soon extend them to 300, or as many as he pleases, thus: let A B C D



represent a flat plate held in position along the lines A B, B C, C D, and D A; now, a pressure applied at P will produce some strain on every point in the periphery, and by the theory of the lever

the strain at *n* is to that at *m* inversely as P *n* to P *m*
" *o* " *q* " *o* P to P *q*
" *r* " *s* " *r* P to P *s*

and so on, for every line that can be drawn through P. The strain at one end of the line is, to the strain on the other end, inversely as the length of the parts; but although each pair of pressures such as (*m* and *n*) (*r* and *s*) vary according to this law, it cannot be demonstrated that the pressures which do not occur in pairs, such as *r* and *m*, follow the same law. There is no reason why they should not do so. But the assumption involves another, namely, that the moment of the force is distributed equally in all directions. In the absence of any reason for assuming that the moment was unequally divided, he had assumed that it was equally divided. This, although it seemed to him the most reasonable and probable assumption, was one that he could not prove; but whether it is exactly true or not, it is demonstrable, that P will bring a greater strain on A D than on B C, on A B than on D C, and generally on the points near to it than on the points distant from it, and, by the law of averages, the resultant of a distributed strain would behave in the same way, that is, would produce the greatest strain on the nearest points, and the least strain on the more distant points. But whether the strain varied in the simple proportion assumed, or in some more complex way, he could not demonstrate in a manner that could not be questioned. If any one considered the moments were unequal in different directions, he could not prove that they were not; but he considered that the burden of proof should fall on those who contended for unequal distribution. The law assumed is that which will produce the least racking strain on the structure.

We have next to consider the arguments based on the results of Mr. Scott's experimental boiler. Each speaker who had tried to defend the old theory had suggested a different method of reconciling it with the facts of the case. In answering Mr. Taylor's questions he would give an answer which seemed to him to be the best possible answer to all the arguments brought forward. The question is, what was the strain on the boiler shell at the different pressures it was subjected to? And he considered that the most reliable facts on the question were derived from other parts of the same boiler.

The boiler bulged in the ends as well as in the shell. In bulging at the ends it stretched the stays, and a comparison between the elongation

of the stays and the stretching of the shell plates appeared to him to be the most conclusive evidence it was possible to bring as to the strain on the shell plates. This comparison is made in the following table:—

Pressure in Boiler. Lbs. per Sq. In.	Average Permanent Bulge on Boiler Ends. In Percentage of Length.	Tension on Stays in Tons per Sq. In. Section.	Average Permanent Increase of Diameter in Percentage of Diameter.	Average Tension on Shell Plate. New Theory.	Tension on Shell Plate. Old Theory.
450	·35	13·75	·19	12·7	18·6
520	1·2	16·0	·37	13·5	21·5
580	2·1	17·7	·9	15·1	24·0
620	2·3	19·0	1·23	16·3	25·7

Now, if the old theory were correct, a strain of 25·7 tons on the shell plate only produced one-half of the extension which a strain of 19 tons on the stays produced. And while a strain of 19 tons on the stays produced an extension of 2·3 per cent., a strain of 18·6 tons on the shell only produced an extension of ·19 per cent., about $\frac{1}{12}$ of the above. But if we compare the tension, as calculated by the new theory with that on the stays, we find a wonderfully close approximation, thus:—

13·75	tons	stretched	stays	·35	per cent.	of their length.
13·5	„	„	shell	·37	„ „	its diameter.
16	„	„	stays	1·2	„ „	their length.
16·3	„	„	shell	1·23	„ „	its diameter.

Mr. Taylor objected, that in taking the extension of the diameter, the tension ought to be taken as that on the plate, not as that on the joint. The reason for taking the joint, was that the strain on the stays was in fact much less than that calculated. For the strain on the stays is calculated on the supposition that the end plates themselves bear no part of that strain, but this is not correct. It takes a powerful hydraulic machine to dish a $\frac{5}{8}$ inch plate like these end plates, even when the plates are red hot, and to dish them cold, as the pressure in this boiler has done, must have absorbed an appreciable part of the pressure on the stays. To make the comparison between ends and shells fair, it is necessary either to make a deduction from the calculated strain on the stays or to increase the calculated strain on the shell. He thought he had made a fair compromise in taking the strain on the shell as that on the weakest part of it, namely, the joint.

Mr. Taylor had also referred to the "barrelling of the boiler." This fact he considered a strong argument in favour of his theory as stated, which showed the pressure greatest at the centre and least at the ends, for

where the tension is greatest the stretching should be greatest. If the old theory were true, the shell should have stretched uniformly, except, perhaps for a few inches near the ends.

The fact that the boiler barrelled between each seam appeared to him to be accounted for very simply. At the seams the plates are doubled, and, therefore, the tension per square inch is reduced to about one-half of that on the single plate, consequently the stretching of that ring will be much less than in the single plate. As a boiler does not act as a series of disconnected rings but as a continuous whole, this causes not a sudden break in the curve of the boiler, but makes each plate curve gently between the seams.

There are many other points to which he would like to refer, but he had said enough to show that, those of his critics, who had condemned his theory as an error, had failed to understand it. They had confused themselves over a very simple mechanical problem, got lost in a fog of abstract theories, and entirely missed the question at issue. He believed that he had proved beyond dispute that the old theory was radically wrong. And that he had indicated the lines on which a true theory must be based.

The ultimate test of all mechanical theories must be experiment, and he trusted that he had convinced his sceptical friend Mr. Taylor that his theory agreed very much more closely than the old one, with the only experimental data available. If any one wished to test the old theory to destruction, let him build and test another boiler similar in all respects to Mr. Scott's, but only half the length. That such a boiler would stand about twice the pressure that the long one stood, is as certain as that a short beam will carry a greater load than a long beam.

The PRESIDENT was sure he spoke the sentiment of their minds when he conveyed to Mr. Spence the hearty thanks of the Institution for his paper which had elicited so instructive and valuable a discussion. They were very much indebted to him. He would not attempt to follow the arguments, it would be vain on his part to do so, and furthermore, they had not the time that evening. He would only remark one thing, he thought one grain of fact was worth a ton of theory, and they had Mr. Scott's boiler before them, and if they wanted to arrive at a true conclusion on this question of boiler scantlings they could not do better than read the papers and the discussion that ensued on Mr. Milton's, Mr. Sennett's, and Mr. Scott's papers, before the Institute of Naval Architects. He had much pleasure in conveying to Mr. Spence the thanks of the Institution for his very valuable paper.

COMMUNICATION FROM MR. A. G. SCHAEFFER.

AKENSIDE HILL, *January 8th*, 1890.

DEAR MR. DUCKITT,—After following the arguments used in Mr. Spence's paper on the strength of boilers, and the discussion that followed, I came to the conclusion that the question is not one which can be easily settled by mathematics, and that reliable experiments would probably throw more light upon the subject. I therefore searched my engineering records to see if I could find any experiments bearing upon the point, and I succeeded in finding two cases where boilers had been tested to destruction. The first is an experiment made by Messrs. John Elder & Co. to test an old boiler taken out of the S.S. "Ban-righ." A full report of this experiment, with drawings, is to be seen in *Engineering* of July 21st, 1876. The second is the testing to destruction of an experimental boiler by the Manchester Steam Users' Association, recorded with drawings in *Engineering* of March 24th, 1876. Both cases are worth careful study. It cannot be denied that the ends of a boiler, and particularly of a marine boiler, play some part in the strength of the boiler, and it is a matter of very great interest to find out what part the ends really do play. I thought it would be a pity to dismiss the question in an off-hand way; and I trust I may be excused for pointing out the two experiments mentioned in my letter as bearing on the subject of Mr. Spence's paper.

I remain, dear Sir, yours faithfully,

ANT. G. SCHAEFFER.

MR. SPENCE'S REPLY TO MR. SCHAEFFER.

NEWCASTLE-ON-TYNE, *20th January*, 1890.

DEAR MR. DUCKITT,—I have to thank you for forwarding to me a copy of Mr. Schaeffer's most valuable contribution to the discussion on the strength of boilers. In seeking for facts by which to test my conclusion I had examined *The Engineer* and *Engineering* for ten years back, but found nothing, except Mr. Scott's experiments, by which to test them. Had I gone far enough back to find the examples quoted by Mr. Schaeffer I would have used them as most striking arguments in favour of my theory. The first example quoted is, I see, a marine boiler, and it burst through shell and ends, exactly in accordance with my assumption. The fracture is reported to have occurred instantly along this line, so that the experimenters were in doubt where fracture commenced. Assume that it

occurred at the weakest point, namely, the tube plate, and every anomaly —and there are several—vanishes. Seeing that we are now working boilers of much greater diameter and at much higher pressures with no stronger tube plates than the one that broke, it is nearly time we gave some attention to their strength, seeing that in every boiler in which the diameter exceeds the length the end plates carry more than half the total pressure.

Mr. Schaeffer's second example is also most instructive; the manner in which every breach of continuity in the circle was proved to be a weak point shows clearly the importance of this continuity, and the error of assuming that a detached section represents the same section undetached. That this boiler finally ruptured in the centre of its length is evidence that even in long boilers such as this the influence of the ends is felt throughout the boiler, otherwise there is no reason why it should break at the centre than at any other point. If the tension was uniformly distributed along the whole shell, the odds would be against it breaking in the centre.

With many thanks to Mr. Schaeffer for this valuable "find,"

I am, yours truly,

J. C. SPENCE.

THE CONSTRUCTION OF MARINE BOILERS WITH A VIEW TO THE USE OF HIGHER PRESSURES.

By CHARLES BASTOW CASEBOURNE.

[Read before the Institution on December 16th, 1889.]

In placing before the members of this Institution a design of a new form of boiler suitable for higher pressures of steam than those now in general use, it would be as well for the writer, before explaining the design, to point out the many advantages, in his opinion, that would accrue from the use of higher pressures.

During the last four or five years the struggle for economy has been marked by the extensive adoption of the triple expansion or tri-compound engine, working at pressures from 140 to 180 lbs. This type of engine has been almost exclusively adopted in new vessels, and in many instances compound engines have been converted into triple expansion by the addition of a third cylinder and higher pressure boilers.

And here it may be stated that before the introduction of this class of engine, 80 lbs. was the most generally adopted pressure.

The well-known Trevithick was the first engineer to introduce steam of high pressure; and although his engines were non-condensing and his boilers of poor construction, yet he successfully proved their superiority in economy of fuel over the low pressure engine, thus showing that steam of high pressure could be used advantageously; and when he and Woolf joined together in introducing the compound engine, it is said they used steam of 60 lbs. pressure.

Steam of higher pressure than he ever anticipated is now being used, both with land and marine engines, and the object of this paper is to attempt to prove that steam of still greater pressures than those now generally adopted may be used with economical results, and that with few alterations the present type of marine boiler may be adapted to safely withstand these higher pressures.

The superiority of the triple expansion engines over the compound is due to the following causes:—

To the higher pressure of steam used, and the higher rate of expansion consequent.

Great variation of temperature in the cylinders, great initial strains, and sudden "drops" in the receivers are thereby avoided.

These apply also to quadruple expansion engines. Increased pressure of steam is easily obtained by a very slight addition in the consumption of fuel, and the efficiency of steam rapidly increases with the increased pressure.

This may be proved :—

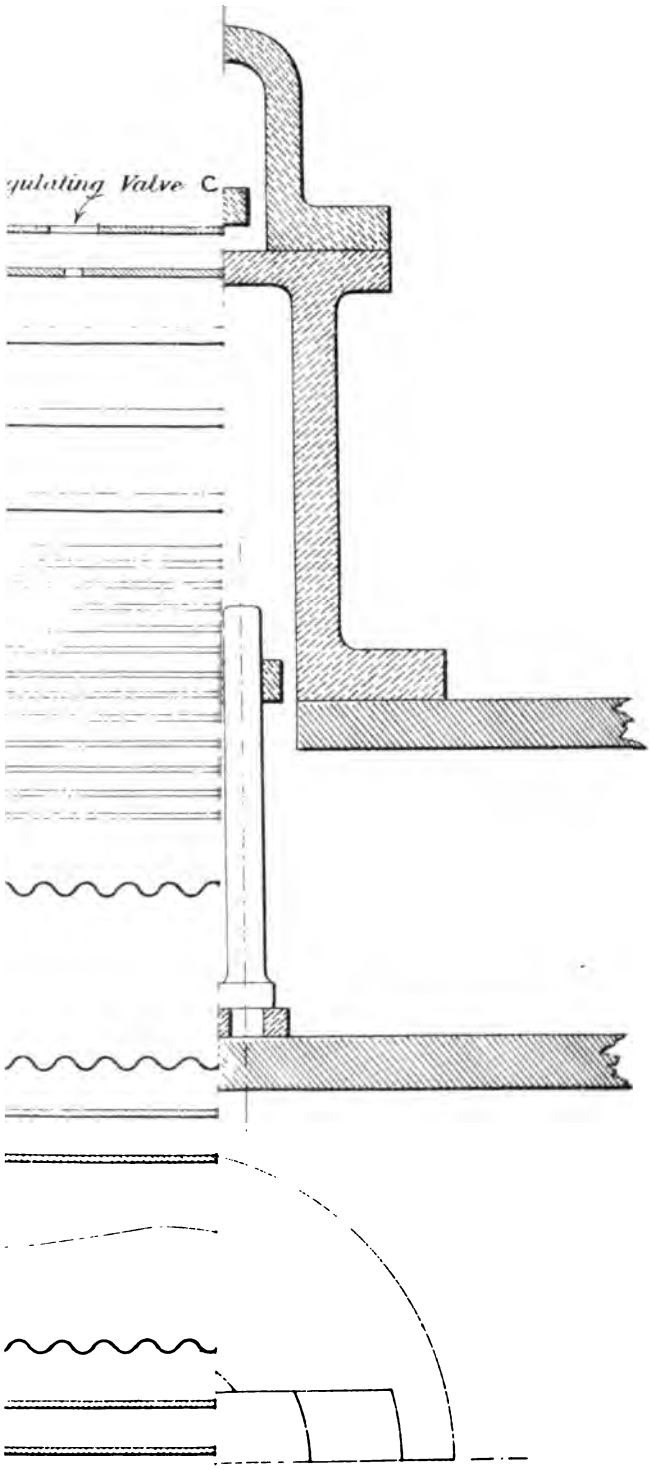
1. The total heat of evaporation of 1 lb. water, from 100° F. and at 312° F. (80 lbs. absolute) is 1108·6° F.
2. The total heat of evaporation of 1 lb. water, from 100° F. and at 358° F. (150 lbs. absolute) is 1122·4° F.
3. The total heat of evaporation of 1 lb. water, from 100° F. and at 401·1° F. (250 lbs. absolute) is 1135·3° F.

If in each case the steam be expanded to a terminal pressure of 10 lbs. absolute, the ratios of expansion will be (1) 8, (2) 15, (3) 25, and the mean pressures corresponding to these initial pressures and rates of expansion will be (1) 30·7, (2) 37·08, (3) 45. If the volume of steam varied exactly as the inverse ratio of the pressure, then these figures would give the comparative values of the steam at the pressures indicated. But as the volume of steam does not vary exactly as the inverse ratio of the pressures, the following will be found to be the more exact relative values in whole numbers: (1) 31, (2) 39, (3) 47.

From this it will be seen that steam of 250 lbs. is capable of doing 30 per cent. more work than steam of 150 lbs., and steam of 150 lbs. 25 per cent. more work than steam of 80 lbs. The latter has been proved by actual practice, and is now an acknowledged fact.

To use steam of 150 lbs. pressure with a compound engine would be very little more economical than to employ steam of 80 lbs., and the same may be said in the case of using any higher pressure than 160 lbs. for triple expansion engines. Yet when 160 lbs. pressure is used in the case of triple expansion engines, it may be said that there is a saving of [illegible] per cent. over the ordinary compound; and supposing a boiler was [illegible] with 160 lbs. pressure it might be anticipated with some certainty that a saving of 20 per cent. would be effected over the triple expansion [illegible] In the [illegible] since quadruple expansion engines are working at [illegible] 160 lbs. only. This is accounted for by the fact that [illegible] found possible to construct a marine boiler [illegible] a higher pressure without either considerably [illegible] increasing the thickness of the shell plates.

rine Boilers for



With respect to the reduction of the diameter, it may be generally known that boilers of the locomotive type have frequently been tried, and many engineers are looking to this class of boiler as offering some advantages in point of weight in comparison to marine boilers, as well as their adaptability for higher pressures. Their performances have, however, not been found satisfactory, and in many instances where large boilers of this type have been in use they have had to be taken out and replaced by the ordinary type of marine boiler.

Two of the principal objections to the locomotive boiler for marine purposes are:—

Firstly—That they require the purest of water, as from their construction they are much more difficult to clean and scale than an ordinary marine boiler.

Secondly—They are apt to prime, owing to the small diameter and limited steam space, whenever the vessel is rolling and pitching in a seaway.

Again, the writer questions very much whether this type of boiler, if required for a certain horse-power, could be made to occupy the same space of boiler room as a marine boiler of the same horse-power.

In a paper read before the Institution of Naval Architects by Mr. W. Parker, March 27th, 1885, he says:—"I have conferred with the principal steel makers in the kingdom on this subject, and am able to say that they agree with me and are decidedly of opinion that steel shell plates of over an inch in thickness, and having a tenacity of over 30 tons, must contain so much carbon as to render them unsuitable for boiler-making purposes, although they may possess the necessary tenacity and ductility to withstand the usual tensile and cold bending tests."

Since this paper was read the uniform quality of steel plates for boiler-making has considerably improved, and they are now able to turn out plates up to $1\frac{1}{4}$ inches and $1\frac{3}{8}$ inches thick, having a tenacity of 30 tons, but this is about the limit.

Mr. J. T. Milton also remarks in a paper read before the same institution, March 30th, 1882: "That these pressures of 140 and 180 lbs. are not likely to be increased for some time to come, unless some type of boiler is introduced which will not necessitate the present style of casing for containing the steam and water, nor the present method of internal firing, as with the obtaining pressures the thickness of plates for these portions have reached the maximum capable of being worked on the one hand, and of being used for the transmission of heat on the other." Taking these matters into consideration it would appear that before

higher pressures can be adopted some improved type of boiler is necesary to withstand these higher pressures which must be so constructed, that shell plates of excessive thickness are not required, nor has the diameter of boiler to be reduced.

Having regard to these requirements the writer ventures to introduce to your notice a form of boiler which will bear the strain of these higher pressures without increasing the thickness of shell plates, or reducing the diameter. In the accompanying sketch it will be seen that Fig. A, Plate VI., is a boiler having two shells, which will hereafter be named as "outer" and "inner" shells. The space enclosed between the shells is termed a "jacket," so that the whole may be termed a "jacketed" boiler. The object of providing a double shell is to charge the enclosed space with steam of a lower temperature than that generated within the inner shell, which is thus relieved of the full pressure of steam within, and is only subjected to the excess of the pressure of steam within, over the pressure of the steam between the two shells. As for example—in the sketch we have a boiler with a shell calculated to stand a working pressure of 150 lbs. to the square inch, employed as the inner shell of a boiler in which steam is generated to a working pressure of 250 lbs., the extra 100 lbs. being neutralised or balanced by an external pressure of the same amount exerted by the steam enclosed between the two shells or jacket.

As the object of providing a space between the two shells is to provide a means of applying a neutralising or balancing pressure to the inner shell, any fluid or gaseous body may be used, but for many obvious reasons steam is the most convenient for the purpose.

It is at once evident that the pressure in the jacket must be constantly and regularly maintained, and in order to provide for this it is necessary to have one or more regulating valves between the two shells. These are constructed on the principle of an ordinary spring-loaded safety valve mounted on valve seats in the inner shell, and so regulated that when the pressure in the jacket falls below that required to be maintained, the valve lifts admitting steam from the boiler until the required pressure is reached, when the valve again closes. The valve in sketch is loaded to 150 lbs., and is externally adjustable. This is effected by having a screwed spindle passing through the cover by means of which the spring may be compressed or released as desired. A valve similar to Fig. C, Plate VI., would be necessary to provide against collapse of inner shell, should the pressure in boiler from any cause be suddenly reduced. Safety valves of ordinary construction would have

to be provided for both boiler and jacket. Condensed water would be drawn away from bottom of jacket to feed pumps. Tubes would have to be thicker, but not much more so than those required for 150 lbs. pressure, as their diameter could be slightly reduced.

The same may be said of furnaces. These could be used of a thickness of $\frac{5}{8}$ inch and diameter of 3 feet, and of a thickness of $\frac{9}{16}$ inch and diameter of 2 feet 6 inches, of Fox's patent corrugated type. Longitudinal stays would have to be pitched closer together and of rather larger diameter, but they need not be of lesser pitch than 14 inches, which would afford ample room for examination and cleaning inside of boiler. Combustion chamber stays would have to be pitched closer together and of rather larger diameter.

Tube plates need not be of any excessive thickness, if more screwed stay tubes are put in. In fact, there seems to have been plenty of room for adapting the present style of marine boiler to higher pressures, in all directions with the exception of the shell, and the writer is of opinion that the double form of shell, as shown in sketch, would overcome this difficulty. Although a boiler with two shells will naturally weigh more than a boiler with one, yet the extra weight will not be so much as might at first be supposed, for by using steam of higher pressure a boiler of smaller diameter is possible, the weight of water evaporated being less. In Fig. B, Plate VI., it will be seen that two forms of riveted circumferential seams are shown, one the ordinary lapped joint double riveted and the other a flanged joint, flanged externally in the case of the "outer" shell and internally in the case of the "inner" shell.

The latter form of joint has been suggested in the event of any difficulty being experienced in repairing an ordinary lap joint should occasion rise.

It has been previously mentioned that this type of boiler is specially adaptable for steam of 250 lbs. for quadruple expansion engines which are at present only using steam of 180 lbs.

This class of engine is becoming more popular every day, and may in time supersede the present triple expansion, even as the latter has taken the place of compound engines.

The writer has not thought it necessary in this paper to go into all the minor details of a new design of boiler, but is anxious to have an expression of opinion from the engineering members of this Institution as to the feasibility of constructing a marine boiler with a double shell to stand much higher pressures than those now in actual use.

DISCUSSION.

Mr. J. T. MILTON said he would like to correct the impression which was given by a paragraph in the paper where reference was made to a paper read by Mr. Parker. Mr. Casebourne seemed to imply that Mr. Parker meant in that paper that plates above an inch thick could not be made. That was not so. The words of Mr. Parker were simply in regard to the quality of the material of steel plates. This paper of Mr. Parker's was read when an attempt was being made to force boiler-makers to use steel of a high tensile strength when experience had not shown it to be suitable for boiler purposes. His (Mr. Parker's) opinion was that plates over an inch in thickness and having a tensile strength of over 30 tons would not be suitable for boiler-making. At that time plates were being made up to an inch and a half in thickness with a tensile strain of about 28 tons, and these were satisfactorily used.

Mr. ALEXANDER TAYLOR—Seeing there would be 80 or 100 degrees difference in temperature in the two boilers he would like to know how the writer proposed to prevent the passage of heat from the inner to the outer boiler? It appeared to him that the inner shell would act as a first-class condenser.

Mr. J. C. SPENCE asked the author of the paper what was gained by the steam space between the two shells? The inner plate required to be strong enough to stand 150 lbs. pressure, and the outer one strong enough to stand 100 lbs. pressure. Therefore, if these two plates were riveted together without any steam space between them, they would stand 250 lbs.; in fact, they would stand a higher pressure, because the outer shell plate would have to be made for a larger diameter than the inner shell. There would be, certainly, some practical difficulties in the way of making a boiler with a double thickness of shell plate, but far less difficulty than in building the proposed boiler. He said that he failed to see any advantage, but saw many disadvantages in the proposed steam space between outer and inner shells.

Mr. JAMES PATTERSON said, this paper seemed to be divided into two parts: the first part showing the gain in economy to be got by using steam at something like 250 lbs. pressure in multiple expansion engines, and the other describing a form of boiler, proposed by the writer of the paper, as a suitable one to withstand this pressure. Mr. Casebourne estimates the gain of economy at about 20 per cent., and he (Mr. Patter-

son) thought before going into the question of the boiler they might see whence that gain was to be obtained. He put down the figures rather differently from what he (Mr. Patterson) worked them out. Theoretically, under the conditions of expansion assumed in the paper, the gain of economy by using steam at 250 lbs. instead of 150 lbs. in unjacketed cylinders was just under 13 per cent., the remainder of the 20 per cent., if it was to be got, must be obtained not from the boiler but from the engine, and must be through some more perfect use of the steam in the engine than in the present triple expansion engine working at 150 lbs. One cause for an extra gain, and with which they gained a good deal in the triple expansion over the compound engine, was the reduced range of temperature in each cylinder. Now, with steam at 250 lbs., and with quadruple expansion engines, there would be a smaller range of temperature than the range at present in the triple expansion engine of 150 lbs., but the reduction would not be so great as that effected by the triple expansion over the compound engine. Therefore, he would say in that case there would not be a proportionately great gain in economy. He also thought a great deal might be done in quadruple expansion engines without going to so high a pressure as 250 lbs. absolute by the gain that would be made by a reduction of temperature. By using, say 200 lbs. boiler pressure, or 220 lbs. absolute, they would get a very great reduction in temperature, and he thought would have a correspondingly great gain in the economy. In the paper the writer gave the ratio of expansions somewhat misleadingly. He said if steam expands from 80 lbs. absolute to 10 lbs. absolute, the ratio of expansion is 8; but the ratio of pressures is 8, which gives with unjacketed cylinders a ratio of expansion equal to 6·5, and similarly with the other ratios. Now, with regard to the boiler, he thought that the great thing which enabled triple expansion engines to come into use was that the ordinary type of marine boiler could be made to stand the pressure required. The difference between the ordinary type of marine boiler and any other he knew of proposed to replace it, was that they could get at any part of the marine boiler for purposes of examination and cleaning, and if 250 lbs. absolute was to be got as they now used boilers, it must be in the same type of boiler, and he did not think this proposed boiler could be called the marine type of boiler. There was an annular space which to be accessible would have to be so large as to do away with any advantage to be gained in getting power out of a given space in the ship. Taking it as shown in the diagrams, the interior of the exterior shell and the exterior of the interior shell could not be got at,

it was, therefore, a departure from the ordinary type of marine boiler in what may be called its most essential feature, and therefore a change for the worse. If they were to have a boiler with inaccessible surfaces, let it be a type of tubular boiler which will give greater power in less space. Mr. Taylor asked how the difference in temperature was to be maintained in the annular space and the boiler itself. He would ask how that difference in temperature might affect the expansion and contraction of the boilers with which they had already to contend in the present type of marine boiler? Many other remarks might be made about this type of boiler, and the difficulty of keeping it clean, but he would make no further remark on the subject.

The discussion was adjourned till the next meeting, to be held on January 13th.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

SIXTH SESSION, 1889–90.

PROCEEDINGS.

FOURTH GENERAL MEETING, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON MONDAY EVENING, JANUARY, 13TH, 1890.

F. C. MARSHALL, ESQ., PRESIDENT IN THE CHAIR.

THE SECRETARY read the minutes of the preceding General Meeting, held in Newcastle-on-Tyne, on December 16th, 1889, which were approved by the members present and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. J. C. Stirzaker and James Patterson to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Baird, Robert, 13, Hylton Terrace, North Shields.
King, Donald, 3, Kent Street, Jarrow-on-Tyne.
Poli, Rodolfo, Chioggia, Italy.
Twigden, George J., 80, King's Road, Canton, Cardiff.

ASSOCIATES.

Corbitt, Michael, The Teams, Gateshead-on-Tyne.
Dixon, Robert, The Teams, Gateshead-on-Tyne.

GRADUATE.

Gibson, W. H., c/o Messrs. Hawthorn, Leslie, & Co., St. Peter's-on-Tyne.

DEPUTATION TO LLOYD'S.

The PRESIDENT said, that with regard to the second paragraph in the minutes, referring to the deputation for representation of shipbuilders and engineers on Lloyd's Committee, he had the pleasure to inform the meeting that Lloyd's Committee had granted, if not entirely, at least a very large proportion of their request, such a proportion, he thought, so far as the Council of this Institution was concerned, they were prepared to accept, subject to the decision of the committee of the other institutions interested. A meeting of the special committee would be held at Carlisle or Newcastle in a few days. They had received the following answer from Lloyd's:—

LLOYD'S REGISTER OF BRITISH AND FOREIGN SHIPPING,
2, WHITE LION COURT, CORNHILL, E.C.,
1st January, 1890.

SIR,—With reference to the printed address forwarded by you in May last, conveying the desire of shipbuilders and marine engineers to be represented on the Committee of Management of this society, I am directed to acquaint you, for the information of the presenters of the document, that the views set forth therein as well as the arguments urged by the members of the deputation, which the committee had the pleasure of receiving on the subject on the 14th November, have occupied the committee's careful attention.

The committee are prepared to admit the reasonableness of the desire expressed by shipbuilders and engineers to be consulted in the alteration of existing rules and the framing of new rules intended to regulate the construction of ships and machinery, and at the same time they do not fail to recognise the advantage the society would derive from the knowledge and experience these gentlemen would bring to the discussion of such subjects.

These considerations have led the committee to make the following proposal, with the object of associating shipbuilders and engineers with members of the committee in their deliberations upon questions affecting the society's rules.

The terms of this proposal are as follow :—

That on all occasions on which it is contemplated to make alterations in the existing rules, or to frame new rules for the construction of ships and machinery, 12 representatives of shipbuilders and engineers—say six members of shipbuilding firms and six members of engineering firms—shall be invited to join the sub-committee of the society, to which the consideration of such matters is delegated.

That this sub-committee, which is designated the "Sub-committee for Surveyors," shall meet at stated times for the purpose of considering questions relating to the alteration of existing rules or the framing of new rules.

The shipbuilding and engineering representatives present at meetings of the Sub-committee for Surveyors, on occasions when such questions relating to the rules are considered, shall exercise the same powers as other members of the sub-committee at such meetings, and shall be allowed fees for their attendance, and also travelling expenses on the same scale as is allowed the outport members of the general committee.

That the election of the 12 shipbuilding and engineering representatives shall be vested in the bodies named in the address.

Questions concerning the procedure of the Sub-committee for Surveyors when enlarged as proposed, the times of meeting, also the period for which representatives of shipbuilders and engineers should be elected, and other matters of detail, are left for further consideration.

As the scheme which is herein proposed will enable shipbuilders and engineers to attain the chief objects they appear to have had in view in approaching the committee, it is hoped that it will be accepted as a satisfactory answer to their address.

I am, Sir, your obedient Servant,

(Signed) A. G. DRYHURST, Assistant Secretary.

J. Muirhead, Esq.,

Secretary of the Committee of the Presenters of the Address,

30, Gordon Street, Glasgow.

It was very gratifying, said the President, continuing his observations, to find that a body such as the Committee of Lloyd's, with its ancient traditions and very high position, had seen fit to grant the request of the various institutions. They would agree with him in thinking that Lloyd's had done wisely and well in acceding to the request presented to them, not only by this Institution, but by the other institutions mentioned in the memorial. Steps would now be taken for the election of such representatives as the various societies should see fit to send to this committee. He thought they might congratulate themselves upon the paper read by Mr. Macarthy, and he (the President) was sure Mr. Macarthy himself would feel much gratified with the result of the discussion which took place on that occasion as helping to bring about this very desirable end.

Mr. H. MACOLL—Mr. President, may I be allowed a word in connection with the proposal by Lloyd's ?

The PRESIDENT—Certainly.

Mr. MACOLL—It is only this, that most of those who have got to do with Lloyd's find there is as much room for argument in the practice as the rules themselves. I think this committee ought to take notice of alterations in the practice as well as the rules—that is, any alteration in the established or usual practice.

The PRESIDENT said Mr. Macoll's suggestion was a very good one. He thought the committee would see that such matters were not forgotten. They would not be satisfied, though perhaps they should speak it with bated breath, only to take up a general position in matters of this kind —that is, those who would have to go on to this committee. The following would, perhaps, give them a more accurate idea of how the matters brought before Lloyd's would have to be treated. The concession to shipbuilders and engineers was no doubt a very great point

gained, but to meet the views of the memorialists it should be clearly understood that the technical representatives of the sub-committee should be the medium of raising any question they deemed necessary upon the existing rules at any time they liked, and not be called upon to discuss only any changes that might be submitted to them at *stated* times. Otherwise, questions the shipbuilders might feel to be burning ones could get shelved for years, until it pleased their advisers to bring them forward. There was the case where vessels were proposed to be built for classification in which the rules were not strictly complied with. What they would require would be that the shipbuilders and engineers should have the right to raise questions and make any submission to the sub-committee, and from them to the general committee, and not that it should come from the general committee downwards. He thought they would find that the thing would be worked out very satisfactorily ultimately. In the meantime, he thought they should be thankful for what they had got, and not forget that they wanted something more.

The discussion on Mr. C. B. Casebourne's paper on "The Construction of Marine Boilers with a view to the use of Higher Pressures" was resumed; after which Mr. E. Hall-Brown read a paper on "High Speed Engines for Cargo Boats."

ADJOURNED DISCUSSION ON MR. CASEBOURNE'S PAPER.

Mr. M. SANDISON resumed the discussion on Mr. Casebourne's paper on "The Construction of Marine Boilers with a view to the use of Higher Pressures." He said Mr. Casebourne was anxious for an expression of opinion by the members of the Institution as to the merits or demerits of his "double-barrelled boiler," as they might call it. He did not think the design, even if practicable, was one which would generally commend itself. The boiler was admittedly heavier than one of the ordinary type, and if the jacket were of any use its inaccessibility was a great objection to it. Then there was the question of several additional mountings to consider. Mr. Casebourne told them that they would require to have one or more regulating valves between the two shells, and a valve to provide against the collapse of the inner shell, and safety valves for both the boiler and jacket. With reference to these regulating valves he did not think the reducing valve was yet patented which would maintain a constant pressure in the jacket. There would be a continual waste from the jacket safety valve. Steam traps or some similar means would require to be provided for getting rid of the water which was bound to condense in the jacket. It would give trouble if drawn off by the feed pump as suggested in the paper. As regards locomotive boilers of large size Mr. Casebourne's remarks would seem to be justified to some extent by the results which had appeared in the daily prints of the trials of the "Sharpshooter" class. Mr. Casebourne was certainly to be complimented on his carefully prepared paper, but he (Mr. Sandison) was afraid that the idea was not altogether novel. He had a notion that the late Mr. Scott Russell made a similar proposition several years ago. Before sitting down he should just like to say that he was somewhat "fogged" as to the functions of the Reading Committee. Members of that committee had been among the most adverse critics of recent papers; in fact, if he remembered rightly, they were told by a member of that committee at the last meeting of the Institution that the paper then under discussion was based upon a fallacy, and that, therefore, it was unnecessary to discuss it further. Now, he would submit to the Council that their papers were circulated all over the world, and that they most frequently appeared without any reference to the discussion whatever. Doubtless a good discussion was provoked during the meeting, but if the dignity of the Institution was to be maintained, as far as papers were concerned, he thought that while calculated to create a discussion they

ought not, in the opinion of the Reading Committee, to be of such a nature as to possibly mislead outsiders. He made these remarks, like Mr. Martell's *Brutus*, not that he loved Cæsar less, but that he loved Rome more.

Mr. J. F. WALLIKER said he believed that the subject of the paper had been fully discussed at a previous meeting, but there was one little point in the design of the boiler before them which might be noticed, and that was that the stays in the steam space were pitched at 14 inches, with a 3 inch stay. They all knew that, in a great degree, the life of a boiler depended upon its accessibility; but with a 14 inch pitch this only left 11 inches to get through, which he did not consider sufficient. Plenty of the Tyne built boilers intended for 150 lbs. pressure had steam space stays pitched up to 17 and 17½ inches, and he thought this was a matter for congratulation and imitation. With regard to combustion chamber plates, he thought that engineers might easily thicken them, and that with safety, and he would point out that plates ¾ inch thick might have a pitch of stay of 10¼ inches, which he considered would be a distinct gain. He believed a paper was now in preparation which would give them more information on the transmission of heat through thick plates.

Mr. CASEBOURNE, in reply, observed first that Mr. Milton had said that in quoting some remarks of Mr. Parker in a paper read by him before the Institute of Naval Architects, he had implied that plates of over 1 inch in thickness could not be made. He did not think that he had misunderstood Mr. Parker, nor did he infer that reliable steel plates of more than 1 inch in thickness could not be made for boilers. If they would kindly glance at the paragraph which followed the quotation, they would see that he said that "plates of 1⅜ inches in thickness can now be turned out, but this is about the limit." Of course it was well known that steel plates of much greater thickness could be and were manufactured, but they would be unsuitable for boiler-making purposes on account of the quantity of carbon they would contain if from no other cause.

Mr. Milton said that plates of 1½ inches in thickness, and with a tensile strain of 28 tons, were now being satisfactorily made and used. This was the greatest thickness he had heard of yet, and, although he did not mean to say that still thicker plates would not yet be made for boilers, yet, as at present manufactured, the tensile strain would have to be reduced, and if plates of 2 inches in thickness or more were required, there would be little advantage in using steel over iron for this purpose.

In reply to Mr. Taylor, he would say that the difference between the temperature of the steam in boiler and jacket would be 401 — 328 = 73 degs. Fah., and that he did not propose to prevent the passage of heat from the inner to the outer boiler. Again, he could not see how the inner shell would make a first-class condenser, as Mr. Taylor seemed to think. He did not say that there would be no condensation, but the condensation which takes place in the shell was amply compensated for by the diminution of condensation in inner shell, as the difference of temperature between steam in inner boiler and that in shell was very small as compared with the difference between the temperature of steam in an ordinary boiler and that of the atmosphere. It might also be said that the jackets of cylinders were mere condensers, although it had been proved by practice and recent experiment that they were a gain, however small, to the economical working of the engine. This he had found to be the case during many years' experience at sea with both triple expansion and compound engines. Of course the jacket as applied to the cylinder had an advantage which could not be claimed for the jacketed boiler, for by preventing condensation in the cylinders priming was avoided, and broken pistons and cylinder bottoms were not now so common as formerly. Every other advantage which a jacketed cylinder might have over an unjacketed one might also be claimed for the jacketed boiler, and instead of acting as a first-class condenser, as Mr. Taylor seemed to think, he was of opinion that it would be the means of preventing condensation, and less moisture would be brought through to the cylinders with the steam.

Mr. Spence said, "why not rivet the two shells together?" Because, to do so, an enormous amount of rivets would have to be put in to make the two plates solid, and the plates would necessarily have to be made thicker to compensate for the number of holes drilled in same, which would add both to the weight and cost. The strain would be unevenly distributed, owing to the impossibility of getting the two plates to bear all over. Steam being an elastic fluid, adapted itself to every portion of the shell, exerting an uniform pressure on every part. As to the difficulty in building a boiler with two separate shells, compared with the method suggested by Mr. Spence, he thought it would be found that the design as shown in diagram was easier to manufacture and less expensive.

With regard to Mr. James Patterson's remarks, he should say that in estimating the gain in economy at 20 per cent. in using steam of 250 over that of 150 lbs. pressure, it was not claimed that the whole of this was due to the increase of pressure alone. A certain proportion of the gain from 5 to 7 per cent. was due to the use of this pressure—250 lbs.—with

four cylinders instead of three, thereby reducing the variation of temperature, as had been stated in the paper read at last meeting. When the triple expansion engine was first introduced a greater economy was manifest than theory showed to be due to the increase of pressure alone, and the latter was found to be the cause. This was an agreeable surprise to many engineers, and went far to ensure the success of this type of engine. It was not put forward that there was an equal gain in this respect of the quadruple over the triple expansion engine, but still there was a substantial advantage. If they took the relative temperatures of the steam at the following pressures, and the number of cylinders in which the steam was expanded, they would see the comparative value of the three types of engines in this respect :—

No. of Cylinders.	Pressure.	Initial Temperature.	Terminal Temperature.	Variation of Temperature.	% of Gain Reduction.
2	80	312	125	93·5	...
3	150	353·3	125	76·1	22·8
4	250	401·1	125	69	11

The calculation on page 98 of the paper was based on the supposition that the steam was moderately moist, and expanded in accordance with Boyle and Marriott's law ($p\,v$ = constant) that pressure varies inversely with the volume.

$$\left.\begin{array}{ll} p_1 = & \text{Absolute initial pressure.} \\ p_m = & \text{,, mean ,,} \\ p_T = & \text{Terminal pressure.} \\ r = & \text{Rate of expansion.} \\ \frac{1}{r} = & \text{Cut off.} \end{array}\right\}$$

$$\textit{Mean pressure} = p_1 \frac{1 + \textit{hyp. log. } r}{r}.$$

$$\textit{Terminal pressure} = \frac{p_1}{r}.$$

$$\textit{Rate of expansion} = \frac{p_1}{p_T}.$$

He did not think that in the proposed form of boiler there was any great departure from the ordinary type of marine boiler now in general use if they excepted the double form of shell. Mr. Patterson was correct in supposing that if the annular space had to be large enough to be acces-

sible, viz., large enough to permit of a man or boy working in this space, then there would not be such a great advantage gained in getting more power out of a less space occupied. But it was not proposed to make the space more than six inches between shell and shell, and even less than that might be found to be sufficient. If proper care be exercised it was very seldom that any trouble was experienced with the shells of boilers; it was the internal arrangements, such as the tube ends, furnaces, and stays that gave the most trouble.

Another form of joint was shown in Diagram B which might possibly overcome any difficulty in this respect, and with this form of joint there was no seam in the boiler which was not accessible. As to its accessibility for cleaning, he failed to see what was going to cause any dirt or deposit in this annular space, as nothing but pure steam was admitted.

Again, with reference to the difference of temperature affecting the expansion and contraction of the boiler, he thought this would be less in the form of boiler shown than in the ordinary type, because the bottom of the boiler would be maintained at a more uniform temperature with the top, which would have a tendency to improve the circulation at that portion of the boiler where most needed, viz., the bottom.

Mr. Sandison spoke of the additional number of mountings necessary for this type of boiler. There were three extra mountings, but he did not think it necessary to take these into account if a substantial gain was to be obtained from the type in question. Although no mention was made of a steam trap in the paper read at last meeting, it was understood that such or a similar contrivance would be required to get rid of the condensed water in the jacket. As regarded the pitch of stays, Mr. Walliker did not think 14 inches was sufficient in order to get at every part of the boiler for convenient working in cleaning, repairs, etc. Well, he had been to sea with various boilers, some with stays pitched as close as 15 inches, and had experienced no serious difficulty in getting at any portion of those boilers either for cleaning or repairs. He did not think an inch less would make any great difficulty, and speaking from experience did not think 14 inches too close so far as pitch was concerned.

He thought it was universally acknowledged that of late too much attention had been paid to the improvement of the marine engine somewhat to the neglect of the boiler, but recently engineers seemed to have become aware that there was room for great improvement in the latter. This was the case both at home and abroad, and it was probable that before long a form of boiler would be introduced which would meet the present requirements.

In conclusion, he would thank the members of this Institution for the patient hearing they had accorded him, and for the fair and impartial criticism of his paper.

The PRESIDENT said they were very much indebted to Mr. Casebourne for having brought before them what he thought he (Mr. Casebourne) believed to be a novel form of boiler, but which, Mr. Sandison had reminded them, Mr. Scott Russell had already suggested something of the same sort; and only ten days ago there had been submitted to him a boiler of precisely the same construction from America and patented in the States, so that they found another illustration of the saying that great minds were often found running in the same groove. Mr. Walliker mentioned in his remarks that possibly or probably they should have a paper on the conductivity of steel and other metals of which marine boilers were made, and the transmission of heat through these metals. He (the President) could only say that he thought a paper of that nature would be of extreme value to their Institution, and he hoped Mr. Walliker or some of his colleagues would favour them with such a paper. This particular question was coming much to the front, inasmuch as they had daily to consider how thin they could keep their furnace plates. Now that they had got to $\frac{3}{4}$ inch plates, it became a question whether they were quite safe in using plates of that thickness or getting the utmost efficiency out of furnaces with such a thickness. He begged to move that their best thanks be given to Mr. Casebourne for his interesting paper, which had led to such a valuable discussion.

The vote was accorded with acclamation.

HIGH SPEED ENGINES FOR CARGO BOATS.

By E. HALL-BROWN, M.I.M.E.

[Read before the Institution on January 13th, 1890.]

Weight economy as defined in Messrs. Marshall and Weighton's paper on "High Speed Engines" is of great importance in all machinery designed for ships, at the same time fuel economy is of equal if not greater importance, even when the matter is studied solely from the standpoint of weight required for propelling the ship.

To make this evident, take the case of two engines indicating 800 horse-power. One engine weighs 90 tons, and the coal consumption is 15 tons per day. The other engine weighs 100 tons, and the coal consumption is 13 tons per day, the boilers being supposed equal in weight and efficiency in each case. It is quite evident that for a voyage of five days the total weight of machinery and fuel will be the same in both cases, and the more economical, although heavier engine would be preferred by most shipowners. This comparison would be still more favourable for the heavier engine upon longer voyages, and might even modify the design of engines for other than cargo steamers.

Enough has, however, been said to show that fuel economy plays an important part in the considerations which should influence the design of engines for cargo boats.

There is still another point, and one which from its importance might claim the first place, viz., the efficiency of the propeller. This is undoubtedly of the highest importance, as the engines only exist to drive the propeller, and the real measure of the efficiency of the propelling machinery of a ship is not the coal per indicated horse-power per hour; but the coal per horse-power per hour, usefully exerted at the propeller.

The efficiency of a propeller is affected by many circumstances, but only one enters into the scope of this paper, that of variation in the number of revolutions.

The experiments described in Mr. Sidney W. Barnaby's little volume

on "Marine Propellers" are, to the writer's mind, the most valuable yet published upon that subject. It is true that the experiments were made upon screws working in undisturbed water, but in all other respects the conditions correspond to those under which propellers ordinarily work, and the laws therefrom deduced may be used with safety in comparing propellers which work under similar conditions.

Fig. 1, Plate VII., is a reproduction of the curve obtained from one screw propeller experimented upon. For convenience in reading, the maximum efficiency is marked 100, and the efficiency at any point in the curve may be read at once as percentages of the maximum.

This curve shows that the efficiency of a propeller increases rapidly with the revolutions until the maximum efficiency is reached; beyond this number of revolutions the efficiency decreases, but more slowly. A slight variation above or below the proper number of revolutions has little effect upon the efficiency, and for this reason it is quite admissible to run the propeller slightly faster than the proper speed, in order to reduce the size and weight of the engines.

If, however, the revolutions are considerably above the number corresponding to the maximum efficiency there is a very considerable loss. Thus, an increase of 50 per cent. means a decrease of about 17 per cent. in the efficiency of the propeller; or, in other words, to give the propelling effect attained at maximum efficiency with 800 horse-power will require at the reduced efficiency about 960 horse-power. It would require a marked increase in weight economy to justify this.

It will be seen, therefore, that it is not justifiable under ordinary conditions to increase the revolutions of a screw propeller 50 per cent. above the number corresponding to the maximum efficiency.

The writer is of the opinion that the propeller now adopted for cargo boats, of about 800 indicated horse-power and 9 to 9½ knots average speed at sea, is a very near approach to the best possible propeller for the work. It is the result of numberless trials, and embodies the best practice of each maker. The problem has been worked out by each maker for himself, and the fact that all have reached approximately the same result must be taken as a proof that that result is not far from a correct one.

As this paper is throughout a comparative one, it will be well at this point to place before you the exact type of ship and engines which was in the writer's mind. To this purpose the ship named "C" in Mr. Robert Thompson's paper on "The Influence of Coal Consumption on the Design of Cargo Steamers" lends itself admirably.

The particulars are as follows:—

Length on load line	281 ft. 8 in.
Breadth, extreme	36 ft. 6 in.
Depth moulded amidships	26 ft. 6 in.
Mean draught from top of keel	21 ft. 4 in.
Displacement	4,766 tons.
Prismatic coefficient	·802.
Engines—Cylinders, diameter...	22 in., 37½ in., 60 in.
Stroke	39.
Average speed at sea	9½ knots.
„ indicated horse-power at sea...	800.
„ revolutions	65 per minute.
Weight of engines with water...	About 105 tons.

This is undoubtedly an economical cargo boat, and the propelling machinery is over rather than under the average efficiency.

At 65 revolutions per minute, it is the writer's opinion that the propeller is making rather more than the proper number of revolutions for maximum efficiency for 800 indicated horse-power and 9·5 knots. However this may be, it is certain that to increase the revolutions 50 per cent. would be to impair the efficiency very materially.

It will be seen, therefore, that the propeller is an effectual bar to the adoption of high speed engines in cargo boats, unless some means is adopted whereby the engines may be run at any desired speed, while the screw shaft still revolves at the speed best suited for the propeller.

Gearing is undoubtedly the solution of the difficulty.

At the first glance this would seem to be a backward step, as it is within the remembrance of many when all large screw engines were geared engines. It is not, however, a step backward, but a step forward that the writer would advise.

Gearing was originally adopted because engineers did not see their way to run the engines fast enough to suit the propeller. Afterwards it was found possible, and indeed profitable, to run the engines somewhat faster, and to couple them direct to the propeller. The next step undoubtedly is to gear the engines, so that while the propeller runs slowly, comparatively speaking, and at the number of revolutions suited to it, the engines may run faster and at the revolutions considered by the designer best suited to them.

This suggestion is not by any means original. It has probably been often made before. It has certainly been made, at least, once before—viz., in the little treatise by Barnaby previously mentioned.

The point is this: if it is necessary or advisable to adopt high speed engines in cargo boats (and to the writer's mind it is certainly advisable, and sooner or later it will probably be necessary), the only economical way is by some arrangement of gearing.

As fuel economy has been shown to have very great bearing upon any question regarding engines for cargo boats, it will be advisable at this stage to enumerate some of the points regarding the steam economy of engines which may be affected by the alterations advocated in this paper.

1st.—In similarly proportioned and similarly situated cylinders, the largest cylinder is the most economical, as the surface of metal exposed to the action of the steam is there least in comparison to the volume of steam in the cylinder.

2nd.—To attain maximum economy the surfaces exposed to the maximum range of temperature should be reduced as much as possible, due consideration being at the same time given to the fact that the total surface must not thereby be increased unduly. Thus, long strokes are beneficial as they permit of smaller surfaces of piston and cylinder cover for the same work done. At the same time, if the cylinder be made too small in diameter and of great length, the surface exposed to steam may be so increased as to nullify any advantage gained by the small ends. Short direct ports, with a maximum capacity within a given surface, are an unmixed good.

3rd.—Other things being equal, that engine will be most economical which has its surfaces, part for part, exposed to the least variation in temperature.

4th.—Water formed within the cylinder, or carried into it by the steam, should be got rid of as water, and not re-evaporated in the cylinder.

5th.—There is a condenser temperature which will give maximum steam economy.

To make this clear, Table A, page 126, and Fig. 2, Plate VIII., have been prepared. Table A shows the work which may be obtained from one cubic foot of steam at 175 lbs. per square inch absolute pressure under various conditions of expansion and condenser pressure. It also shows the number of foot-pounds per thermal unit obtained under those conditions. The method of computing this is fully explained in the Appendix, page 126.

Fig. 2, Plate VIII., shows the same results in a graphic and perhaps a clearer form.

From the table and curves it is evident that there is a certain condenser temperature corresponding to maximum economy for each ratio of

expansion. It is also evident that this temperature is not the lowest attainable as is usually supposed by scientific men, nor is it that corresponding to a back pressure of about 3 lbs. per square inch as is usually supposed by sea-going engineers.

This is a matter of some importance, as the efficiency of a steam engine is usually supposed to be indicated by the formula $\frac{T - t}{T}$, which would indicate that the lower the temperature t is made the greater would be the efficiency of the engine. Of course this does not indicate any fallacy in the laws of thermo-dynamics, but merely a wrong application of these laws. It is the first time, as far as the writer is aware, that attention has been drawn to this fact.

6th.—Other things remaining the same, increased speed of revolution is productive of increased economy.

As was pointed out by Mr. B. F. Isherwood, in the discussion on Mr. Willan's paper on "Non-Condensing High Speed Engine Trials," before the Institution of Civil Engineers, increased speed of revolution means increased power, if the size of the cylinders and the steam pressure remain constant; but if it is required to keep the power constant the size of cylinders must be reduced, and the gain due to the increased speed of revolution may be more than balanced by the disadvantage of the smaller cylinders.

There are, of course, many other points influencing the steam economy of engines, but these seem to the writer to be those chiefly affected by an increased speed of revolution, and by the other changes advocated in this paper.

To return to the particular part of the subject at which the above digression—if such it is—was made. It is evident that an engine geared as already described may be run at whatever speed of revolution the designer may think fit without in any way affecting the propeller, and so for the present the propeller may be left out of the question.

With any design of engine the maximum pressures which the parts are capable of transmitting are exactly calculable, and this pressure should not be exceeded. It is, therefore, evident that if the piston rod, say, is designed to transmit safely the load due to the maximum pressure of the steam and no more, this load should not be exceeded, however caused.

It is usual to consider the reciprocating masses connected with the piston of an engine to embrace the piston, piston rod, crosshead, shoes, and half of the connecting rod. This is sufficiently accurate for practical

purposes, and will be adhered to in this paper. The pressures required to accelerate these reciprocating masses at the ends of the stroke are found from the formulæ:—

For top or cover end $f = \cdot 0003427 \times W \times n^2 \times r \times \frac{R + r}{R}$.

For bottom or crank end $f = \cdot 0003427 \times W \times n^2 \times r \times \frac{R - r}{R}$.

Where f is the required force in pounds.
W „ reciprocating mass in pounds.
n „ number of revolutions per minute.
r „ radius of the crank in feet.
R „ length of the connecting rod in feet.

Instead of finding the total pressure, it will be convenient to find the pressure per square inch, and in that case the only alteration is, that W will represent the reciprocating mass per square inch of piston.

Let us take the engine "C" before mentioned as an example. The reciprocating masses will be somewhat as under:—

High pressure	6·25	pounds	per square inch
Intermediate pressure	3·20	„	„
Low pressure	1·95	„	„

And at the speed of revolution given (65 per minute), the pressures required for acceleration will be as given below:—

	Top.	Bottom.
High pressure	18· 4	11·02
Intermediate pressure	9· 4	5·65
Low pressure	5·73	3·44

The above are pressures per square inch, and are calculated upon the assumption that the length of the connecting rod equals four cranks.

The effect of the above pressures is to reduce the effective pressure transmitted to the crank pin at the beginning of the stroke, and to increase it towards the end of the stroke, and is so far beneficial in tending to equalise the pressure transmitted.

If, however, the above engine were run at 105 revolutions per minute, the pressures required for acceleration would be much increased, and would be somewhat as here given:—

	Top.	Bottom.
High pressure	47·9	28·7
Intermediate pressure	24·6	14·73
Low pressure	14·9	8·98

In this case the pressure required to accelerate the reciprocating masses at the top of the stroke in the low pressure cylinder is approxi-

mately equal to the total pressure upon the piston, and to go much beyond this point would be to render the piston rod subject to greater stress than it was designed to bear.

In this case, therefore, the proper limit of speed has been reached, if indeed it has not been overstepped, for that type of engine. It is, however, quite possible to reduce the reciprocating masses and still retain a factor of safety of ten throughout.

Probably, after making all the reduction which could be allowed in a cargo boat, the reciprocating masses would be as under:—

High pressure	5·5	pounds	per square inch.
Intermediate pressure	2·35	"	"
Low pressure	1·15	"	"

With these reciprocating masses, an engine with a stroke of 2 ft. 6 in. and a connecting rod equal to four cranks, and making 145 revolutions per minute, the pressure required to accelerate the reciprocating masses in the low pressure cylinder would be about 15 pounds per square inch.

This great increase in the number of revolutions would allow of a corresponding decrease in the size of the engine, which might now be:—

Diameter of cylinders	17 ins., 27 ins., 44 ins.
Stroke	2 ft. 6 ins.
Reduced weight	about 52 tons.

It will be seen that a reduction of about 50 per cent. may thus be made in the engines.

Such an engine is, however, open to many objections. It is a very delicate mechanism, and its bearings require often and careful adjustment, as a slight slackness which would cause no perceptible noise at 65 revolutions would become a serious matter at 145 revolutions.

In fact the engine is a near approach to the high speed engines of the Navy, and would require a large and highly trained staff of engineers. It is indeed doubtful if even then it could be kept at its original efficiency as a machine.

From the standpoint of steam economy it is probably on a par with the 65 revolution engine, as the gain due to the increased speed of revolution would probably be balanced by the loss due to the much smaller cylinders.

Such an engine properly designed, and well and thoroughly jacketed, of the ordinary triple expansion type, could be depended upon to develop 1 indicated horse-power for 15 lbs. of steam at 175 lbs. absolute per hour, corresponding in a good boiler, and with good coal to about 1·5 lbs. of coal per indicated horse-power per hour, or for 800 indicated horse-power about 12·8 tons per 24 hours.

As an engine more suited to the requirements of the mercantile marine in being less sensitive, and at the same time more economical, than the foregoing, while being a decided advance upon the ordinary practice as regards weight economy, the writer begs to place two designs before the Institution.

Figs. 3, 4, and 5, Plates IX., X., and XI., represent design No. 1. It is a single-acting triple expansion engine, with three cylinders over three cranks set at 120 degs. The engine is jacketed throughout, the jacket steam entering the covers first and then passing downwards to the cylinder jackets.

The working steam acts only upon the tops of the high pressure and initial pressure pistons, the bottoms of these cylinders being in open communication with the next receiver. The low pressure cylinder is somewhat different, being a cylinder using steam somewhat after the style of the Cornish pumping engines—that is, the steam acts first upon the top of the piston, and when that approaches the bottom of the stroke the two ends of the cylinder are put in communication, thus equalising the pressure on each side of the piston. The return or upward stroke is made in this state of equilibrium. The bottom then exhausts into the condenser.

It will be seen, therefore, that the expansion in the low pressure cylinder is divided more or less distinctly into two stages, the upper side of the piston and the top cover having the higher temperature, and the lower side and bottom of the cylinder only being subjected to the temperature of the condenser.

In each of the points previously mentioned, as tending towards economy of steam, this engine has an advantage over an ordinary engine.

1st.—The cylinders have twice the capacity of the cylinders of a double-acting engine as usually designed for the same pressure and number of revolutions.

2nd.—The ports are short and direct, and the surfaces exposed to the maximum range of temperature are kept small and are efficiently jacketed.

3rd.—Part for part there is less variation of temperature than in an ordinary double-acting engine. Thus, the cover and upper side of the piston and steam ports are exposed to a range temperature, corresponding to the range in pressure to which these are subjected, but the lower part of the cylinder walls are subjected to a much smaller range of temperature, as they are never in contact with high pressure steam. Figs. 6 and 7, Plate XII., show this graphically; these diagrams show the range of temperature and amount of exposed surface for the high pressure cylinder of this engine and for the high pressure cylinder of an ordinary double-acting engine of equal power.

4th.—Water in the cylinder is got rid of as water. This can never be the case with water on the top side of the piston of an ordinary double-acting engine, and is rarely so even on the bottom side of the piston. This will be plain when it is remembered that the exhaust port is closed before the piston reaches the top of its stroke, at which point only could water upon the top of the piston escape as water.

5th.—The condenser temperature is the best possible. This of course is not inherent to the design, but may be common to any engine.

From a practical point of view, and looked upon only as a machine, the advantages of the design are sufficiently striking.

There are no glands subjected to boiler pressure.

All the pressures are in one direction, and hence the bearings will run without knock until quite worn out.

Those two points in themselves brand the design as practical.

An engine of this design could run with safety at about 170 to 175 revolutions per minute.

The reciprocating masses are :—

High pressure	5·5	pounds per square inch.
Intermediate pressure	2·16	" "
Low pressure	1·02	" "

For 800 indicated horse-power at 175 revolutions the engine would be as follows :—

Diameters of cylinders	17 ins., 28 ins., 47 ins.
Stroke	3 ft.
Connecting rod	4½ cranks.

The pressures required to accelerate the reciprocating masses are :—

	Top.	Bottom.
High pressure	105·8	67·3
Intermediate pressure	41·5	26·4
Low pressure	19·55	12·46

The high initial pressure in the low pressure is admissible, because of the division in the range of temperature. This, however, is the fastest speed at which the writer would care to run this design of engine.

A set of theoretical diagrams for this design are shown in Fig. 8, Plate XIII. The estimated consumption of steam at 175 lbs. absolute pressure is under 13 lbs. per indicated horse-power per hour, corresponding to about 1·3 lbs. of coal per indicated horse-power per hour under the same conditions as before, or about 11·15 tons per day for 800 indicated horse-power.

The weight of this engine would be about 65 tons, and the price

about the same as an ordinary double-acting engine having the same size of cylinders, that is to say, much less than an engine of the ordinary type, and working at the ordinary number of revolutions.

As already stated, this is the limit to which the writer would be prepared to go with this design of engine. For ordinary work he would recommend 150 to 160 revolutions, with a corresponding increase in the size and weight of the engines.

At this speed there would be no need for a high initial pressure in the low pressure cylinder, and the range of temperature in each cylinder would be fully under the control of the designer.

For still higher speeds of revolution the writer would propose an engine after No. 2 design (see Fig. 9, Plate XIV). This is a single-acting engine similar to No. 1 design, with the addition of three air cylinders tandem over the steam cylinders.

The office of these air cylinders is to allow the pistons to alternately compress and expand the contained air. The reaction thus obtained being utilised to retard and accelerate the reciprocating masses. There is a non-return valve at each end of these cylinders by which air is automatically admitted when the pressure within the cylinder falls below that of the atmosphere, so that at each end a cylinderful of air at atmospheric pressure is compressed into the clearance space and then allowed to expand.

By properly proportioning these air cylinders, as regards size and clearance space, it is quite possible to retard and accelerate the reciprocating masses at any speed, however great, without any undue stress being thrown on any part of the machinery. Fig. 10, Plate XV., shows a diagram from one of these cylinders, designed to allow of nearly all the work of retarding and accelerating the reciprocating masses being done by the air cylinder. Of course any less amount may be thus taken up, and the remainder used to equalise the pressures produced by the steam in the cylinder.

Such an engine is of necessity somewhat more complicated than that shown in design No. 1; but it is also more perfect, and for speeds above 175 revolutions per minute with an engine of 800 horse-power some such device would be necessary.

For starting the engines means would be provided whereby some or all of the air would escape from the air cylinders.

An engine of this design to indicate 800 horse-power at 200 revolutions per minute would be of the following size :—

Diameter of cylinders	16 ins., 25½ ins., 44 ins.
Stroke	3 ft.
Weight	About 58 tons.

A theoretical diagram for this engine is shown in Fig. 11, Plate XV. It will be seen that in this case there is no necessity for a high initial pressure in the low pressure cylinder to accelerate the reciprocating masses, and so the utmost advantage can be taken of the division in the range of temperature in that cylinder.

Upon the whole the writer is of the opinion that design No. 1 is to be preferred at this present time for cargo boats, and that the speed of 150 to 175 revolutions with that design will give such results as would justify its adoption.

Throughout this paper the writer has spoken of the piston, piston rod, etc., as the reciprocating masses, because they are the greatest in magnitude and velocity, nevertheless, the effect of high speeds upon the stresses coming upon the valve gear cannot be neglected in designing engines for high speed. The pressure required to accelerate the valve and gear can be found from the formulæ given for the piston and piston rod, and this has to be added to the pressures required to overcome the friction of the valve.

With regard to the gearing of the shaft, which is a very important detail, there will be little difficulty in designing suitable wheels. With improved metals and high-class machine moulded teeth there need be no fear. It will of course be necessary to interpose springs between the teeth and the propeller to prevent a sudden jar coming upon the teeth at any time.

Helical gear is out of the question, owing to the end motion of the screw shaft, but stepped gearing lends itself admirably to the required purpose, and with, say, four steps, it should be possible to make a gear which will not be heard even in the engine room.

APPENDIX.

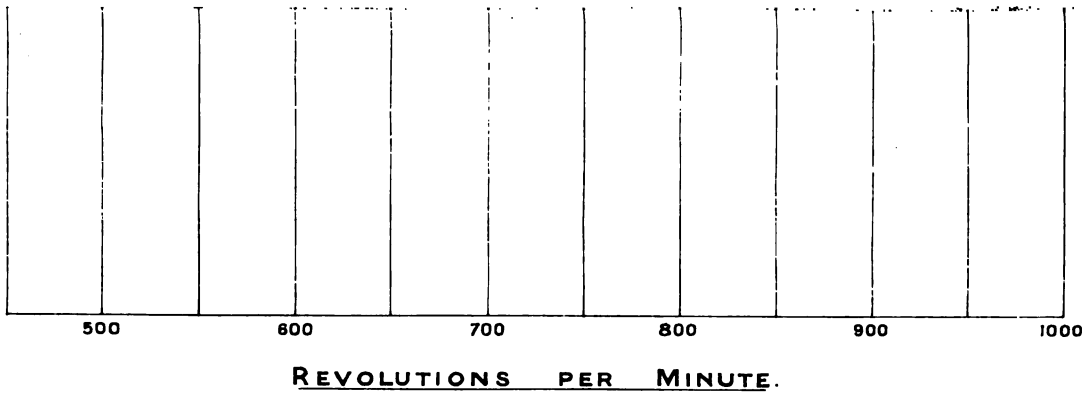
TABLE A.

TO SHOW THE EFFECT OF VARIATION IN THE CONDENSER PRESSURE.

THE FIGURES REFER TO THE WORK OBTAINABLE FROM ONE CUBIC FOOT OF STEAM AT 175 LBS. ABSOLUTE PRESSURE.

(a) Ratios of Expansion.	(b) Total Work without Loss or Back Pressure in Foot Pounds. PV = Constant.	(c) Net Work Obtainable, No Back Pressure, in Foot Pounds.	Condenser Pressure, ·085 lbs. per Square Inch. Back Pressure in Cylinder, 1·585 lbs. per Square Inch.		Condenser Pressure, ·5 lbs. per Square Inch. Back Pressure in Cylinder, 2 lbs. per Square Inch.		Condenser Pressure, 1 lb. per Square Inch. Back Pressure in Cylinder, 2·5 lbs. per Square Inch.		Condenser Pressure, 1·5 lbs. per Square Inch. Back Pressure in Cylinder, 3 lbs. per Square Inch.		Condenser Pressure, 2 lbs. per Square Inch. Back Pressure in Cylinder. 3·5 lbs. per Square Inch.	
			(d) Net Work in Foot Pounds.	(e) Foot Pounds Obtained per Thermal Unit.	(f) Net Work in Foot Pounds.	(g) Foot Pounds Obtained per Thermal Unit.	(h) Net Work in Foot Pounds.	(k) Foot Pounds Obtained per Thermal Unit.	(l) Net Work in Foot Pounds.	(m) Foot Pounds Obtained per Thermal Unit.	(n) Net Work in Foot Pounds.	(o) Foot Pounds Obtained per Thermal Unit.
10	83,226	62,419	60,137	129·0	59,539	132·9	58,819	133·9	58,099	133·9	57,379	133·5
11	85,627	64,220	61,710	132·3	61,052	136·2	60,260	137·2	59,468	137·1	58,676	136·5
12	87,819	65,864	63,126	135·4	62,408	139·3	61,544	140·1	60,680	139·9	59,816	139·2
13	89,838	67,378	64,412	138·1	63,634	142·0	62,698	142·7	61,762	142·4	60,826	141·5
14	91,705	68,779	65,585	140·7	64,747	144·5	63,739	145·1	62,731	144·6	61,723	143·6
15	93,444	70,083	66,661	143·0	65,763	146·8	64,683	147·3	63,603	146·6	62,523	145·5
16	95,070	71,302	67,652	145·1	66,694	149·4	65,542	149·2	64,390	148·4	63,238	147·1
17	96,597	72,448	68,570	147·1	67,552	150·8	66,328	151·0	65,104	150·1	63,880	148·6

To illustrate Mr. E. Hall-Brown's paper "on High Speed Engines for Cargo Boats."



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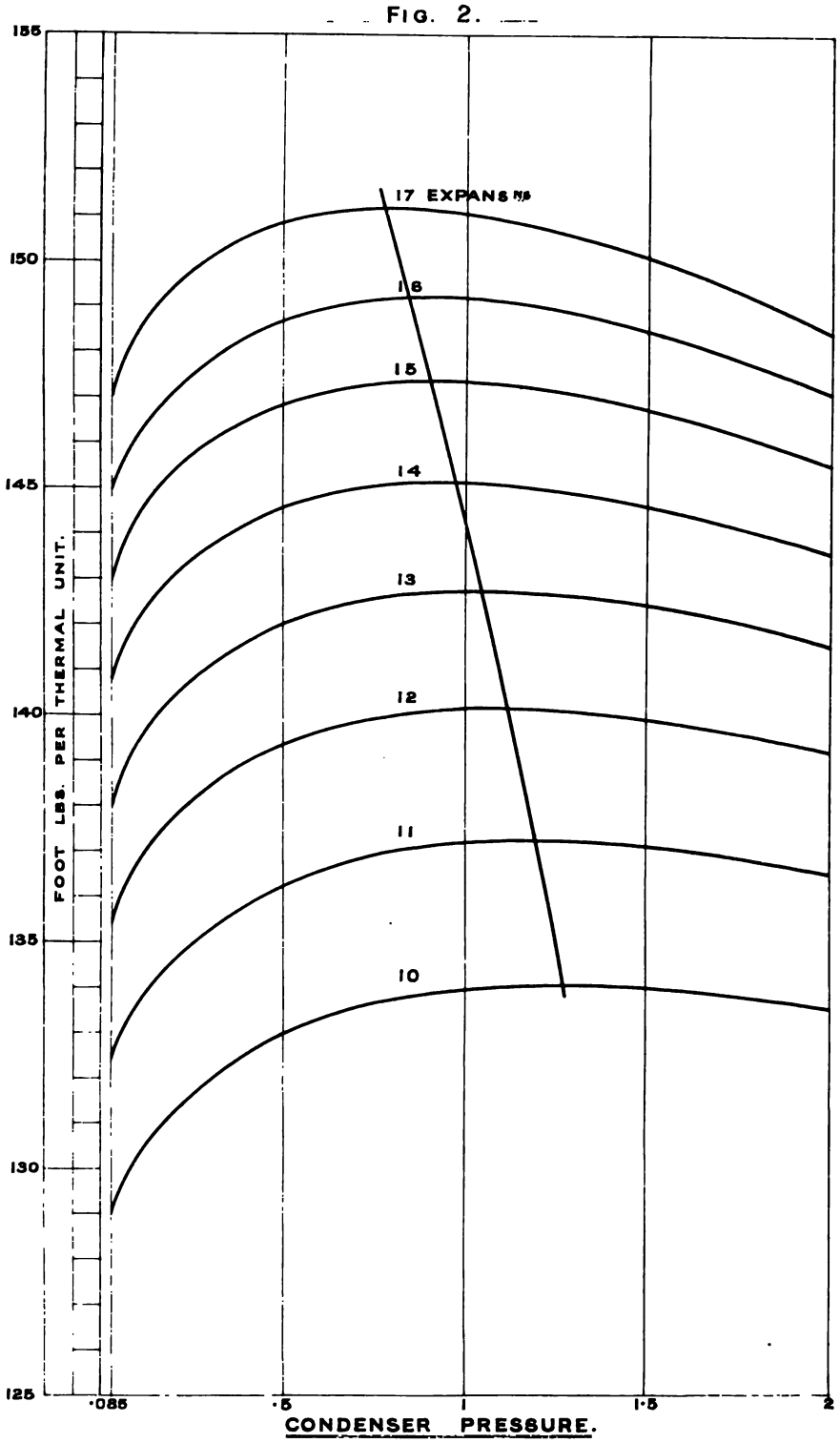
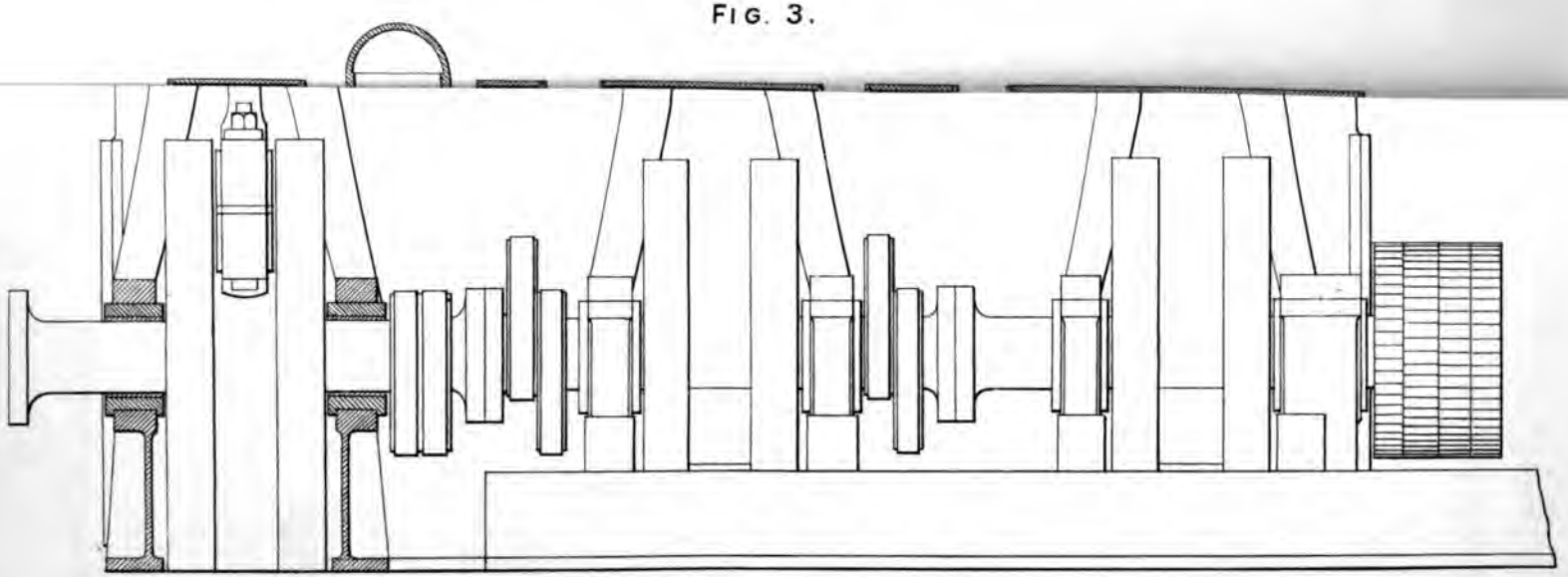
To illustrate Mr. E. Hall-Brown's paper "on High Speed Engines for Cargo Boats."

FIG. 2.



To illustrate Mr. E. Hall-Brown's paper "on High Speed Engines for Cargo Boats."

FIG. 3.



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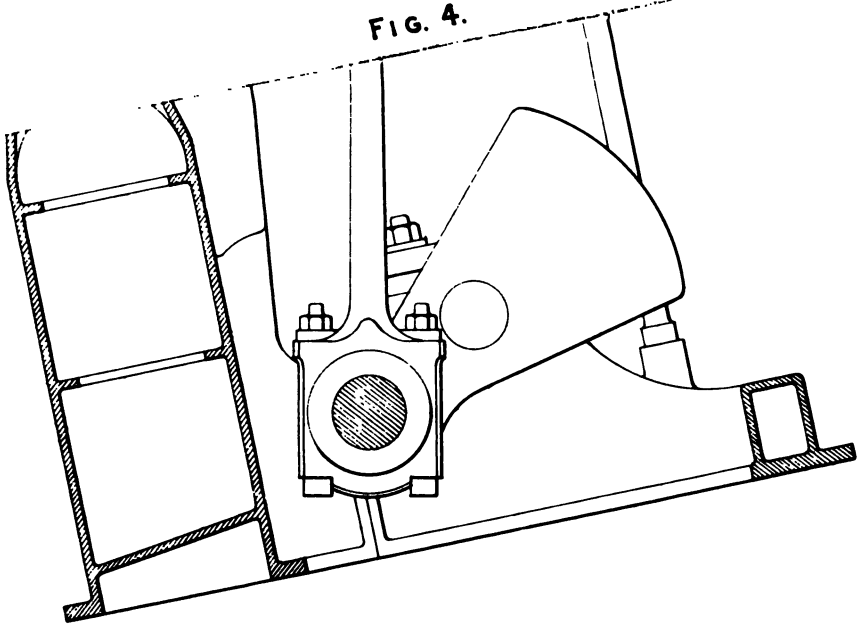
To illustrate Mr. E. Hall-Brown's paper "on High Speed Engines for Cargo Boats."

FIG. 4.

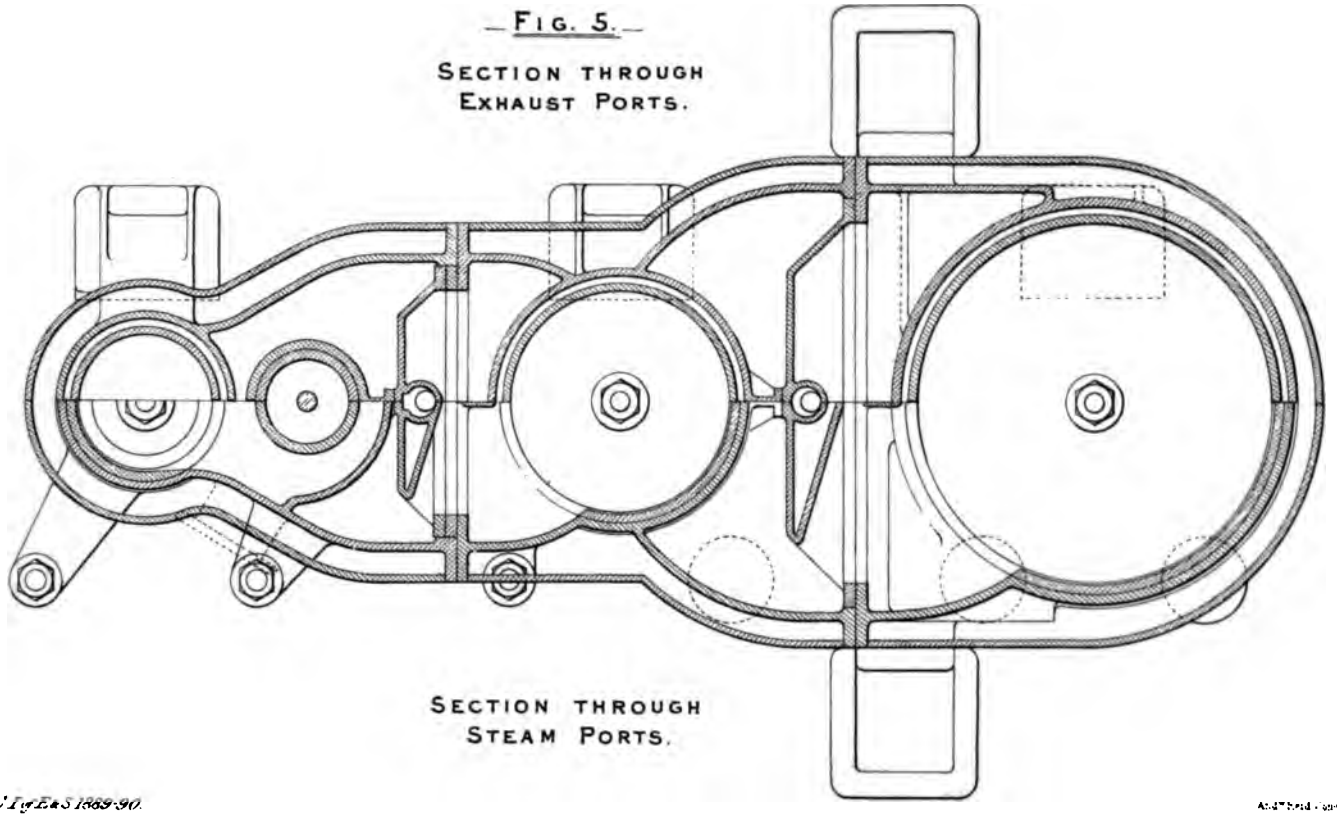


Alf. Reid Sons & Wilkins Newcastle

To illustrate Mr. E. Hall-Brown's paper "on High Speed Engines for Cargo Boats."

— Fig. 5. —

Section through Exhaust Ports.



Section through Steam Ports.

Proceedings N.E.C.I. of E. & S. 1889-90.

Andrew Reid Sons & Co. Lithos Newcastle

APPENDIX.

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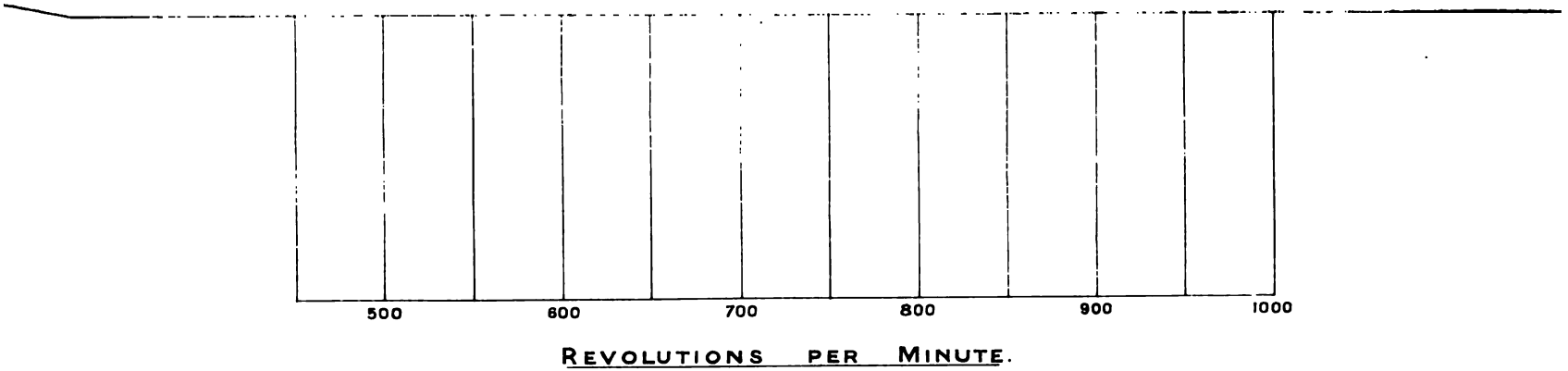
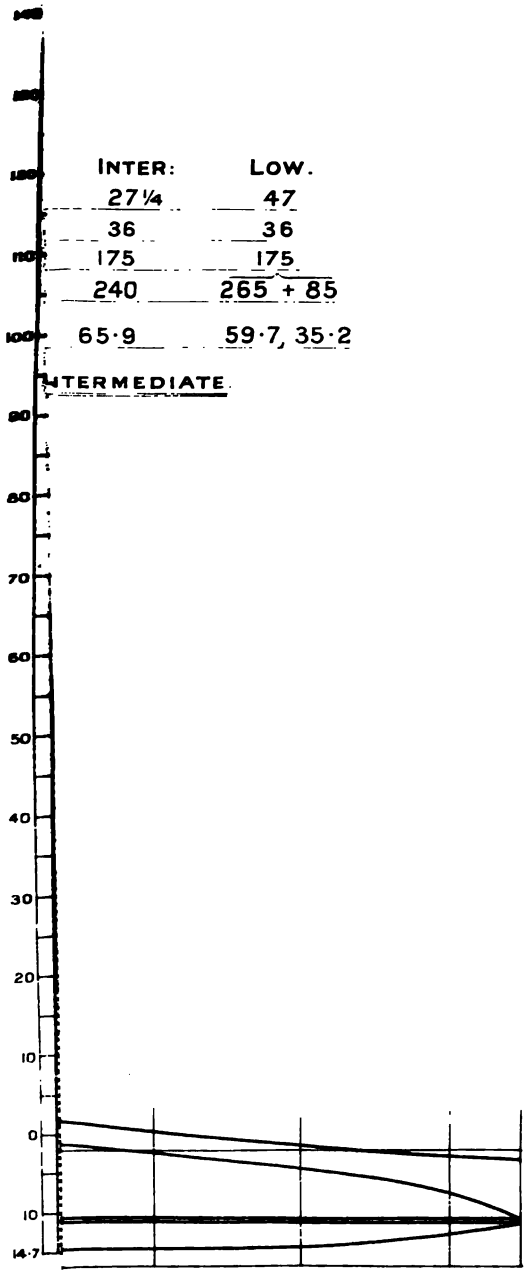


argo Boats."



A. Reid & Sons, Lithos, Newcastle

To illustrate Mr. E. Hall-Brown's paper "on High Speed Engines for Cargo Boats."

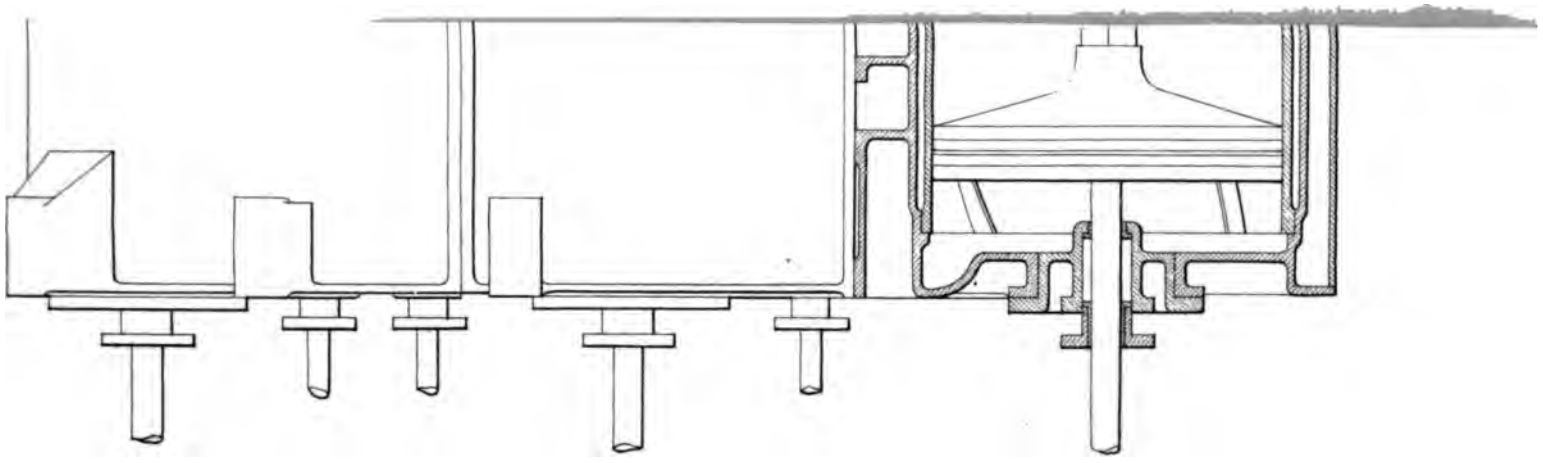


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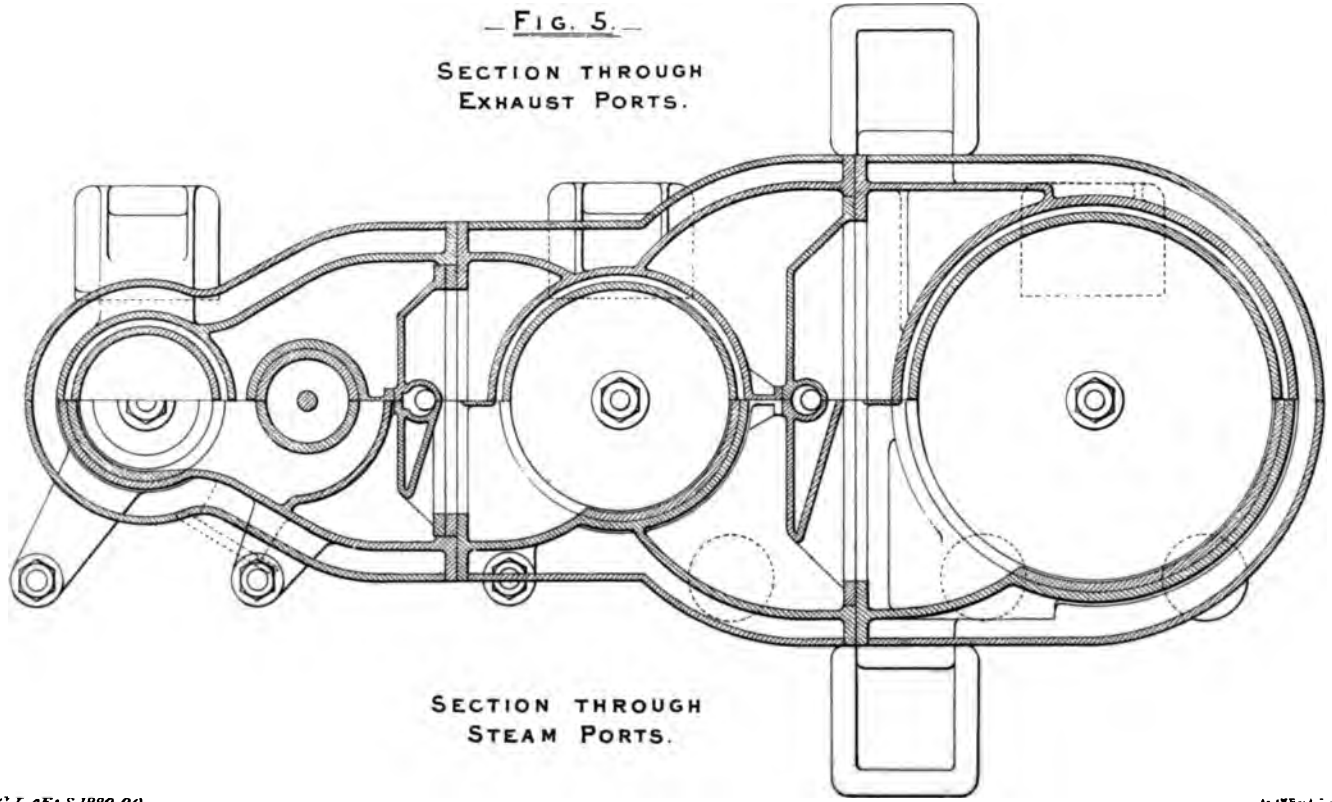
FIG. 5.

SECTION THROUGH EXHAUST PORTS.



SECTION THROUGH STEAM PORTS.

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Calculation of Table A.

Work done by steam $= A\,p\,\frac{L}{E}\,(1 + \log. E)$.

Where A is area of cylinder in square inches,
p is the absolute pressure of steam per square inch,
L is the length of the stroke,
E is the ratio of expansion.

Take 10 expansions.
175 lbs. absolute pressure.
144 square inches area of cylinder.
1 cubic foot of steam.

It is evident that the expanded steam will occupy 10 cubic feet.
Therefore stroke is 10 feet.

$$\text{Work done} = 144 \times 175 \times \frac{10}{10}\,(1 + \log. 10).$$
$$= 144 \times 175 \times 3{\cdot}3026.$$
$$= 83{,}226 \text{ (column } b\text{)}.$$

As this amount of work could not be obtained in any engine because of losses due to initial condensation, etc., a reduction of 25 per cent. is made to cover these losses:—

$$\frac{83{,}226 \times 75}{100} = 62{,}419 \text{ (column } c\text{)}.$$

There has, however, been no reduction made for back pressure in the above. To allow for this, it is assumed that the back pressure in the cylinder will be $1\frac{1}{2}$ pounds more than the condenser pressure.

Thus in columns d and e the condenser pressure is ·085 pounds per square inch, and the back pressure in the cylinder is assumed to be 1·585 pounds per square inch.

The net work with this back pressure becomes:—

$$62{,}419 - (1{\cdot}585 \times 144 \times 10) = 60{,}137 \text{ (column } d\text{)}.$$

The amount of heat expended to produce this work is found as follows:—

Weight of 1 cubic foot of saturated steam at 175 lbs. absolute	·3905 lbs.
Total heat above 32 degs. of 1 lb. steam at 175 lbs. absolute	1,194·4 th. units
Water heat corresponding to condenser pressure of ·085 lbs. per square inches above 32 degs.	0

∴ Heat required to generate 1 cubic foot of steam at 175 lbs. absolute from water at condenser temperature ... ...$=\cdot3905(1{,}194\cdot4-0)$
$=466$ th. units

and

Foot pounds of work obtained per thermal unit$=\frac{60{,}137}{466}=129\cdot0$ (column *e*).

TABLE B.

SUMMARY OF ENGINES MENTIONED IN THIS PAPER.

Description.	Revolutions per Minute.	I.H.P.	Weight of Engines with Water.	Weight of Engines per I.H.P.	Consumption (Estimated) per 24 Hours.
Ordinary type Triple Expansion Engine, on Three Cranks	65	800	105 tons.	294 lbs.	13 tons.
High Speed Triple Expansion Engine, ordinary type ...	145	800	52 „	146 „	12·8 „
Design No. 1	175	800	65 „	182 „	11·15 „
Design No. 2	200	800	58 „	162 „	11 „

DISCUSSION.

Mr. JAMES PATTERSON said he was sure they were all very much indebted to Mr. Hall-Brown for bringing before them an interesting paper full of suggestiveness. It was one from which they might all derive information. It was impossible within the prescribed limits of time to attempt a detailed criticism of a paper which opened so many subjects as this one did, and he would therefore confine the remarks he had to make to two points. These were, he considered, the two principal heads of the paper, viz.: the propeller and the proposed engine for driving it. The writer of the paper thought that the present propeller in cargo steamers must be taken as the best possible for reasons he gives. He (Mr. Patterson) differed from him, and pointed out that the very same reasons would prove that the present engines in cargo steamers must be the best possible, therefore there was no occasion for better, or no room for better. Further, to make room for the introduction of the proposed new type of engine, it had to be shown that the efficiency of the propeller was reduced very quickly with the increased number of revolutions. The first step in this process was to give the diagram given by Mr. Barnaby in his treatise for efficiency of the propeller, which showed the efficiency falling somewhat rapidly as the

revolutions increased. He did not think, however, that it represented the actual state of the case with regard to the efficiency of the marine propeller as the revolutions were increased. In the first place that curve represented the result of experiments on a peculiar type of propeller, of one fixed surface-ratio, and one fixed pitch-ratio, both of which might be altered so as to give better results at the higher revolutions; and in the second place the model was working in still water, and therefore was not under the conditions in which a ship's propeller works. The results must therefore be used with caution. If, however, they took, for argument sake, the 65 revolutions to be the best for the 800 horse-power, and 9½ knots, as far as the propeller is concerned, to increase this to 80 revolutions was a very small step, and he thought it might be done without any reduction in the total propulsive efficiency for several reasons. One reason (he did not know whether there was very much in it, but to him there appeared to be something) depended upon a consideration of the augmented resistance caused by the action of the screw. Take Mr. Froude's analysis of the power required to drive a ship as sufficiently correct for comparative purposes.

Let E.H.P. = effective horse-power.

Let S.H.P. = ship's horse-power, that is the total I.H.P. less the I.H.P. due to slip, then Mr. Froude divides the indicated horse-power required to drive the ship into that required to overcome.

1st.—The resistance of the ship	=	E.H.P.
2nd.—Augment of ship's resistance due to the negative pressure caused by the action of the screw	=	·4 E.H.P.
3rd.—Water friction of screw	=	·1 E.H.P.
4th.—Constant friction of engines	=	·143 S.H.P.
5th.—Friction due to working load	=	·143 S.H.P.
6th.—Air-pump resistance	=	·075 S.H.P.

∴ by addition of these six elements—

$$\text{S.H.P.} = 1{\cdot}5 \quad \text{E.H.P.} + {\cdot}361 \text{ S.H.P.}$$
$$= 2{\cdot}347 \text{ E.H.P.}$$

Add slip $\frac{1}{10}$ S.H.P. and I.H.P. = 2·582 E.H.P.

Therefore, of the 800 I.H.P. in the case under consideration, only 310 is effective horse-power.

Now, suppose that the revolutions are increased from 65 to 80, and that to do this a smaller propeller is used with greater slip. The quantity of water thrown aft by this propeller will be less than in the first case, and consequently the augment of the ship's resistance will be

less (experiment confirms this), or, in other words, the hull efficiency will be greater. Take an extreme case and suppose that the augment of resistance is reduced from ·4 E.H.P. to ·2 E.H.P., what would be the total I.H.P. ?

S.H.P. = E.H.P. + ·2 E.H.P. + ·1 E.H.P. + ·143 S.H.P. + ·143 S.H.P. + ·075 S.H.P.

$$\therefore \text{S.H.P.} = 2{\cdot}03 \text{ E.H.P.}$$

and

$$\text{I.H.P.} = 2{\cdot}24 \text{ E.H.P.}$$

$$\text{I.H.P.} = 2{\cdot}24 \times 310 = \underline{\underline{714}}$$

Of course, it is not pretended that there is a reduction even approaching this in extent, but the diminution of this augment of resistance will neutralise, at least to some extent, the supposed loss of efficiency of the screw, which, with this slight increase of revolutions, cannot be very great. Our everyday experience also seems to show that the quicker running engine is at least as efficient in total propulsive effect as its slower brother. Compare now the double-acting engine at 80 revolutions with the engine Mr. Hall-Brown proposes to drive the ship. It is a single-acting engine to run at 160 revolutions. Both these engines will be of the same size, and the initial friction of each will be the same, and consequently the power required to overcome the initial friction at 160 revolutions will be double that at 80 revolutions. In Mr. Froude's analysis we must therefore write ·286 S.H.P for horse-power due to the initial friction. There was also the friction of the working load, which in the down stroke of the single-acting engine will take just the power required altogether for the double-acting engine. Something must be added for the upstroke—let us say one-fourth (which is a moderate estimate), giving horse-power due to friction of working load = ·179 S.H.P. For this engine we therefore get

S.H.P. = E.H.P. + ·4 E.H.P. + ·1 E.H.P. + ·286 S.H.P. + ·179 S.H.P. + ·075 S.H.P.

$$\therefore \text{S.H.P.} = 3{\cdot}26 \text{ E.H.P.}$$

and

$$\text{I.H.P.} = 3{\cdot}586 \text{ E.H.P.}$$

but

$$\text{E.H.P.} = 310$$

$$\therefore \text{I.H.P.} = 3{\cdot}586 \times 310 = \underline{\underline{1{,}111}}$$

which he thought was a very large increase of power to be compensated for by a gain of efficiency in some other part of the engine.

The President, on adjourning the discussion till the next meeting, observed that the disadvantage of not having seen the diagrams prepared by Mr. Hall-Brown to illustrate his paper rendered it almost impossible for many members to take up the matter in the masterly way Mr. Patterson had done.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

SIXTH SESSION, 1889–90.

PROCEEDINGS.

FIFTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE SUBSCRIPTION LITERARY SOCIETY, FAWCETT STREET, SUNDERLAND, ON FRIDAY EVENING, FEBRUARY 14TH, 1890.

F. C. MARSHALL, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the previous General Meeting, held in Newcastle-upon-Tyne, on January 13th, 1890, which were approved by the members present and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. James Patterson and M. Sandison to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Findlay, John Taylor, 11, Nelson Street, Sunderland.
Goddard, George Arthur, 100, Park Crescent, North Shields.
Mavor, Alfred E., 4, Elmbank Crescent, Glasgow, N.B.
Mills, William, Bridge Crescent, Sunderland.
Williams, T. Fitzroy, 64, Linskill Terrace, Tynemouth.

ASSOCIATES.

Cassap, William, 23, Cawley Road, Victoria Park, London, N.E.
Muller, J. C. F., 28, Vieille Route, Antwerp.

DEPUTATION TO LLOYD'S COMMITTEE.

The PRESIDENT said that, with regard to Lloyd's Committee, the Glasgow Shipbuilders' Association was arranging for a meeting to be held in Carlisle somewhere about the 20th February, when further steps would be taken as to waiting upon the Committee, and the Institution would be represented.

The discussion on Mr. E. Hall-Brown's paper on "High Speed Engines for Cargo Boats" was then resumed, after which a paper by Messrs. W. KILVINGTON and ALEX. TAYLOR on "Boiler Furnaces" was read.

ADJOURNED DISCUSSION ON MR. E. HALL-BROWN'S PAPER ON "HIGH SPEED ENGINES FOR CARGO BOATS."

The PRESIDENT said, they were all very much interested in the paper which Mr. Hall-Brown read at the last meeting in Newcastle, and he believed they would have upon it a very interesting discussion. There were a good many novelties suggested by Mr. Hall-Brown, and, as somebody had said, there was a great deal of original thought in it. He therefore hoped there would be no delay in discussing the whole paper in all its varied aspects.

Mr. R. L. WEIGHTON said, he thought the meeting would agree with him that the author of the paper deserved to be complimented, very largely because he had had the courage to bring forward proposals of such marked divergence from practice. He was also to be complimented on the full and careful way in which he had gone into the details of his scheme, and he (Mr. Weighton) hoped that adverse criticism would not have the effect of discouraging but rather of stimulating him to renewed effort, though possibly on somewhat different lines. The first thing that struck one on reading the paper was that while the author started out with the intention of promoting two important economies—weight and fuel—he ended in proposing for this purpose a type of engine which—other things being equal—doubled the weight (viz., a single-acting engine), and of which the ultimate fuel economy was at the best hypothetical. The gist of the whole matter hinged upon the *propeller* question, and on the assumption made in the paper, that sixty-five revolutions per minute was the highest speed of revolution, from an economical point of view, for an ordinary cargo vessel of about 9½ knots and 800 indicated horse-power. Now he (Mr. Weighton) submitted that this assumption was unwarranted even on Mr. Barnaby's theories. He (Mr. Weighton) did not think Mr. Barnaby himself had intended any such general and sweeping application to be made of his conclusions, especially seeing that his rules would give a propeller about 18 feet diameter running at fifty-two revolutions as the most suitable propeller for the ship in question. This was in his (Mr. Weighton's) opinion absurd. Mr. Barnaby neglected *surface* entirely, and this alone was sufficient to limit the range of application of his conclusions to the particular type of propeller with which he experimented. It would be well were Mr. Hall-Brown to give the full particulars of the propeller he recommended for the 9½ knot vessel. So far as his (Mr. Weighton's) experience had

gone, he could not by any means say that the best possible propeller for such a vessel had been arrived at, because there was no uniformity amongst engineers in regard to these matters, each maker had his own notions and put in his own proportions of propeller. Every ship was in a sense an experiment in propellers. If this was so then there was no necessity for having recourse to a special type of high speed engine and gearing such as the author recommended. The same weight economy and fuel economy might be got by using an engine of the ordinary double-acting type, and running at one-half the speed of the author's engine. It was well to examine into the assumptions underlying the proposals of the author. In the annexed table, page 135, No. 1 was the ordinary standard engine mentioned in the paper; No. 2 was the author's engine intended to supersede No. 1. It would be observed that while No. 1 was working at 22 lbs. reduced to low pressure, No. 2 had 29 lbs. This he (Mr. Weighton) did not think possible on the same basis as No. 1 for economy, and allowing a reasonable increase of economy to No. 2 due to various causes. He would, therefore, substitute the larger engines, No. 3 for No. 2, as being the smallest sizes to give the power at the required revolutions. The weight of No. 3 would be 79 tons. Now, instead of single-acting, let us take No. 4 double-acting as a substitute for No. 3. No. 4 weighs 79 tons (same as No. 3) and being double-acting it need only run at half the revolutions, *i.e.* 87·5. In this last engine all gearing is done away with, and he (Mr. Weighton) thought he would certainly—if he had a choice between Nos. 3 and 4—choose No. 4, and would risk any small loss which might be feared in efficiency of propeller. The fuel economy of No. 4 would be at least as high as No. 3, and all gearing is done away with. There were some good features in the author's design. These were—first, small ranges of temperature in the cylinders; second, a large amount of compression at the top of the low pressure cylinder; third, the single-acting nature of the engine rendered it suitable for unusually high speeds, though it was doubtful if at 175 revolutions it be needful to adopt the single-acting type; fourth, the great facility it offered for efficient draining of the cylinders and receivers. There were also, however, some rather undesirable features. These were—first, the turning effort on the crank-shaft was only half what it was in double-acting engines, and he surmised the friction on the bearings would be vastly increased on this account; second, the absence of any compression at the bottoms of any of the cylinders; third, the great inequality in the maximum and in the mean loads on the bearings. In round numbers

the maximum load on the high pressure was 24,300 lbs., on the intermediate pressure 25,000 lbs., and on the low pressure 34,700 lbs. The last exceeded the first by 42 per cent. Again, the indicated power of the high pressure was 238, of the intermediate pressure 240, and of the low pressure 350. The last exceeded the first by 47 per cent. Fourth, the engine would not be so readily handled as the double-acting type. The inertia question did not appear to be quite clearly put in the paper. He did not understand how the speed of the engine could be determined by the strength of the piston rods, so long as steam was driving the engines, but he may have misunderstood the author's meaning on this point. Altogether the paper was most suggestive, and one which opened up problems of a very far reaching nature, the discussion of which could not but be conducive to the progress and advancement of engineering. The only drawback was that for the discussion of such problems in any adequate fashion not one night but several would be required.

TABLE.

No.	Engines.	Weight in Tons.	Revolutions per Minute.	Mean Pressure Reduced to Low Pressure Cylinder.	Single or Double-Acting.
1	22—37½—60 / 39	105	65	22	Double.
2	17—28—47 / 36	65	175	29	Single.
3	19—30½—52 / 36	79	175	23½	Single.
4	19½—32—54 / 36	79	87½	22	Double.

1.—Ordinary standard engine.

2.—Mr. Hall-Brown's engine Too small to give the power with the economy assumed.

3.—Mr. Hall-Brown's engine enlarged to give the power required.

4.—Ordinary standard engine equal to No. 3 in weight and fuel, and running at half the revolutions and without gearing.

Mr. W. KILVINGTON said that in the very exhaustive way in which Mr. Weighton had treated the paper a great many things which he had intended to refer to had been dealt with. He must, however, congratulate the author of the paper as heartily as Mr. Weighton had done, and anything he had to say would be taken by Mr. Hall-Brown as merely friendly criticism. He had gone over the calculations in the same way as Mr. Weighton. 800 horse-power was not the greatest power applied

in cargo boats, and if they doubled that, and took a ship that went at the same speed, they found, adopting the same formula, that they required a propeller about 26 feet. Of course that propeller could not be applied to cargo boats, or any vessel, so far as he was aware, so that Mr. Hall-Brown's solution of the problem entirely broke down. As to the weight of the connecting rod, Mr. Brown had said that it was usual to take half the weight of the connecting rod. He (Mr. Kilvington) thought that was not usual, and was most certainly wrong, which would be apparent to anyone if they considered that the centre of gravity of the connecting rod moved through the same space as the other reciprocating parts. He had the same difficulty as Mr. Weighton in knowing what Mr. Brown meant by there being a greater strain on the piston rods due to acceleration. He could not see how a greater strain could be brought on the piston rods than that due to the maximum pressure of steam, even neglecting the weight of the piston which, however, should be taken into consideration. He failed to see how the pressure of steam would cause more strain than was equal to that pressure. What would happen if more pressure was required for acceleration would be that the speed would not be quite uniform but be diminished at the top and bottom of the stroke. With regard to the condenser, he should like Mr. Brown to go more fully into an explanation of that. He understood that there was a certain back pressure in the condenser, which was the most economical, and in the paper it is stated that this back pressure depends on the ratio of expansion, but he must say that Mr. Brown had not converted him to that view, as the efficiency, according to the table given at the end of the paper on page 126, is always in the column under 1 lb. pressure. Since the ratio of expansion was altered 70 per cent, and the most effective results found in the same column, he thought there was no strong proof that the condenser pressure varied very much with the ratio of expansion. The design generally he believed would be useful if it were necessary; it was excellently thought out and was very well arranged, but he thought very much more reason for its necessity would have to be given before it would ever be tried.

Mr. Alex. Taylor quite agreed with the last two speakers that the paper under discussion was a valuable one; its suggestiveness was its chief merit. There were just two points he would like to speak about—1st, he was under the impression that the engine, Fig. 3, Plate IX., was designed to save weight, but he thought that the cylinder and cylinder cover jackets added considerably to the weight without corresponding advantages, and to show that they may even be a disadvantage it is only necessary to examine the intermediate cylinder. The writer of the paper

proposes to jacket this cylinder and its cover with steam at boiler pressure, that is with steam at 370 degs. This cylinder is supplied with steam exhausted from the top of the high pressure cylinder—it has free access to the bottom of the high pressure cylinder and intermediate pressure steam chest, therefore if the intermediate pressure cylinder cover is jacketed, why not also jacket the high pressure cylinder bottom and the intermediate pressure steam chest bottom? Again, the exhaust steam from the intermediate pressure cylinder (measured on the theoretical diagrams) will never be more than 240 degs., and it surrounds the outside of the steam jacket and also passes up the inside of the cylinder, and is thus exposed to an enormous amount of surface, jacketed with steam at 370 degs., or a difference of 130 degs., and he would ask—Is not the principal effect of this particular jacket to send a large quantity of extra heat to the low pressure cylinder and condenser?

Mr. J. R. FOTHERGILL said, it appeared to him somewhat extraordinary that at the present age engineers had to admit the propeller had not advanced beyond the experimental stage. He hoped in the interest of shipowners such was not altogether the fact. Did it not seem remarkable, when we considered the modifications and improvements which, particularly in late years, had been made in the engines that the propeller was still in its infancy? One would imagine engineering firms of repute had tabulated such data (seeing so many cargo boats now "run" the measured mile), that they could without hesitation design a satisfactory propeller for any steamer. He was glad to find a great improvement had taken place in the casting of propellers with satisfactory results, but he was of the opinion that even in the case of cargo steamers it would pay to make a bronze propeller and work it up true to the angle required. He thought the principle feature of this paper was at what speed could propellers of cargo boats be run? He had listened with great interest to the remarks made by prior speakers, and regretted he could not agree with the views expressed by his friend Mr. Weighton relative to the speed of propellers. Without going into theory he might remind them the first consideration in designing a propeller was its diameter. Now, in modern cargo boats in which shallow draught is considered an important feature, the diameter of the propeller was somewhat affected by the following considerations:—The propeller must be sufficiently submerged so as not to break the surface of the water, and it is necessary to keep the propeller somewhat up above the keel line as cargo boats frequently take the ground. He held, for a cargo boat, it was essential to efficiency to have a large diameter propeller, and thought Mr. Weighton had entirely

overlooked that factor which played such an important part, namely:—The lines of the ship. In the steamer referred to in the paper, the prismatic coefficient is ·802 equal to ·75 block coefficient, the block coefficient of a fine lined ship is ·45. It must be self-evident the effect this difference would have on the propeller. Mr. Froude fully treated this subject in his paper:—"The Determination of the most Suitable Dimensions for Screw Propellers," read before the Institute of Naval Architects, 1886. By reference to the Transactions you will find Mr. Seaton in discussing the paper particularly referred to steamers having a coefficient of ·75 and sometimes even higher, and stated as follows:—"We find with these cargo boats we are bound to have a screw of large diameter. We may settle the surface and the pitch to suit our own ideas, but to get anything like good results, especially with a ship whose stern lines are full, we are bound to have the screw of large diameter." Mr. Froude in his reply stated:—"If Mr. Seaton will work out the dimensions of screws suitable for various ships, according to the diagrams accompanying this paper, he will find that an increase in fulness of form will give precisely the results he has found in practice, namely:—The necessity of an increase in diameter of screws." Mr. Froude also points out:—"The skin friction resistance of screw blades varies as the area of surface and as the square of the speed." Mr. Sydney Barnaby, who was assistant to Mr. Thornycroft, and conducted nearly the whole of the extensive experiments carried out by Mr. Thornycroft, and is most fully recognised by Mr. Froude as an authority on the propeller, writes as follows:—"If a screw propeller is placed behind a bluff stern, so that its supply of water is imperfect it will draw in water at the centre of the driving face and throw it off round the tips of the blades exactly like a centrifugal pump. He (Mr. Fothergill), in the face of what he had quoted, thought there could be no two opinions as to the necessity for a large diameter propeller for cargo boats, and if the skin friction increased as the square of the speed, it appeared to him impossible to run such a propeller at high speeds, because if you reduced the area sufficient to get up the speed the blades would not be of sufficient strength to stand the resistance let alone have form to give efficency, and therefore on the question of the propeller he agreed with Mr. Hall-Brown. He did not propose to say much on the question of the engines, because in the main he agreed with what Mr. Weighton and others speakers had said. Due to want of compression on the under-sides of the pistons, he thought there would be great liability to "knock," particularly in a sea-way, and especially when "throttling." Assuming there was a continuous downward

pressure on the pistons, he found the friction on the bearings would be very great as compared with a double-acting three-crank engine. He thought it desirable to look at the question from a commercial point of view, and assumed the author's proposal had reference to the modern type of steamer. Was the author aware the modern cargo steamer of steel, as built at the Hartlepools, when loaded with coals in the Tyne and completely full, including bunkers, was barely down to her load-line mark? Therefore if she was 100 tons lighter in her engines it would be of no advantage; of course when loading dead-weight there was a gain in relation to the weight saved. Then in the Indian trade at least 75 per cent. of steamers fill themselves with home cargo without being down to their load mark. There is also the question of light ship where any reduction of dead-weight might have to be made up by increased size of ballast tanks to the loss of cargo as already the draught light ship is barely sufficient. Take a steamer on a usual voyage, say to Aden, Bombay, and home, and assume she can load an extra 50 tons (reduced weight of machinery) outward and 25 per cent. of 50 tons homewards, based on present rate of freights and price of bunkers, we have as follows:—

	£	s.	d.
50 tons outward to Aden, at 14s. 6d.	36	5	0
Less 10 % brokerage, etc.	3	12	6
	32	12	6
Less 1s. per ton discharging	2	10	0
Net outward gain	£30	2	6

	£	s.	d.
25 % of 50 tons Bombay cargo home, at 25s. ...	15	12	6
Less 5 % brokerage, etc.	0	15	7½
	14	16	10½
Less 1s. per ton discharging on 12½ tons ...	0	12	6
Net homeward gain	14	4	4½
„ outward „	30	2	6
Total gain per voyage ...	£44	6	10½

(Of, say, from 3 to 3½ months.)

The speed of the ship is 9½ knots, therefore she would be 60 days steaming on the voyage. If we divide the amount gained (£44 6s. 10½d.) over 60 days it gives 14s. 9d. per day. Say, the average price of bunkers (assuming none are taken the other side of

the canal) are 20s. per ton, we thus see that a saving of $\frac{3}{4}$ ton per day in the consumption would equal the gain due to a reduction of 50 tons in the weight of machinery; or, to put it another way, suppose you increase the speed of the ship a good $\frac{1}{8}$th of a knot per hour you will make the voyage in 59 instead of 60 days: a saving of 1 day in a ship of this size is equal to the above gain, which might be obtained by a careful and well-designed propeller. He (Mr. Fothergill) on the above showing could not agree with the author that it was desirable to adopt high speed engines in cargo boats, seeing we now have good running and economical triple engines. It appeared to him most undesirable to make such a radical change as advocated by the author, the extra attendance and knowledge required by the engineering staff and the probable extra cost of upkeep would probably swallow more than the gain. The saving in consumption which Mr. Hall-Brown estimated he would make he looked upon as purely hypothetical. In practice he was of the opinion there would be no saving whatever. At all events he could not see sufficient encouragement to accept the proposition. He had intended to have said something on the question of steam jackets, but had already exceeded the time at his disposal, and therefore would only say he had gone somewhat into this question, and was fully of the opinion—in cargo boats—you would get more value out of your steam by using it in the cylinder than in the jacket. He was speaking practically. In conclusion, he desired to congratulate Mr. Hall-Brown and admired his boldness of conception, and thought he must feel very gratified by the discussion his paper had elicited.

Mr. W. A. F. Crawford was of opinion that increased speed of revolution was conducive to economy, because in a well-jacketed cylinder—he did not mean steam jacketed, the use of which was aptly compared to the process of carrying water up a hill to get work from it by letting it run down again, but jacketed with a good non-conductor—the heat passing from the cylinder walls and covers would be constant as soon as it had attained its maximum rate, and would be independent thereafter of the speed of revolution. If this rate was reached in our own present type of engine, at say 50 revolutions per minute, he did not see that anything could be gained by the author's design, as it would be clear that if the same engine was run at 150 revolutions per minute, two-thirds of them would be performed without loss by conduction from the cylinder covers and walls. He did not think that anyone would use gearing for the purpose of getting increased speed of revolution so long as they could adapt twin screws, nor did he think the author's engine would run so

noiselessly as was anticipated, because the bearings would not wear at the same rate, and this would cause quite as much knock as in the present practice. He joined with the other speakers in congratulating the author on his pluck in bringing his well-reasoned views before so critical an Institution.

Mr. J. M. ALLAN could not agree with Mr. Hall-Brown's estimate of the economy to be obtained by using single-acting engines. In the ordinary double-acting (60 inch cylinders × 39 inch stroke) engine taken by Mr. Hall-Brown as his standard, 800 indicated horse-power is developed on a reduced mean pressure of 22 lbs., whereas in his proposed single-acting engine (Figs. 3, 4, and 5, Plates IX., X., and XI.) a reduced mean pressure of 29 lbs. is necessary. To produce these pressures a ratio of expansion of 15 in the case of the double-acting, and 12 in the single-acting engine would probably be required. Under these circumstances 962,000 cubic inches of steam per minute would have to be supplied to the double, and 910,000 cubic inches to the single-acting engine, which makes a difference of 5·4 per cent. in favour of the latter, not 14·2 per cent. as given in the tables. But in this estimate nothing has been allowed for the friction and driving of the gearing. For this purpose a margin of 5 per cent. does not appear excessive, so that the boilers would have at least to supply the same amount of steam in each case, and no saving would result. The principal advantage in the design seemed to be in not exposing the glands to full boiler pressure. Mr. Hall-Brown in estimating the pressures required to accelerate the reciprocating masses had made the necessary correction for a finite connecting rod, but had omitted to make any for the fact of the engines being vertical. He should have deducted the weight (per square inch of piston) of the reciprocating parts from the pressure required to accelerate them at the top of the stroke, and added it to the pressure required for the same purpose at the bottom. This would bring the top and bottom pressures much more nearly equal than they are shown to be in the tables. Mr. Hall-Brown also states that the piston rod has to bear a stress due to the pressure required to accelerate the whole of the reciprocating masses. This is a mistake, because the piston only can stress the piston rod screw; the effect of the whole comes on the connecting rod bolts alone.

The PRESIDENT intimated that if there were any who wished to criticise the paper further they could send their remarks to the Secretary. He would now call upon Mr. E. Hall-Brown to reply.

Mr. E. HALL-BROWN said, before replying in detail to the very able and kindly criticism to which his paper had been subjected, he begged leave to thank the President and the members generally for the way in which the paper had been received, and for their many kind and encouraging remarks.

The object of the paper was to place before the Institution a solution of what appeared to the writer a very important problem, viz., how to combine increased weight economy with increased fuel economy in engines for cargo boats. Undoubtedly the final decision upon the worth of these proposals could only be obtained by actual trial, nevertheless he hoped to be able to show that very few of the objections urged to these proposals had any real basis.

Mr. James Patterson was quite right in saying that the experiments from which the curve in Fig. 1, Plate VII., was plotted, were made with a peculiar propeller. It was a Thornycroft propeller. Nevertheless, the curve there shown was a characteristic one for all propellers, as might be seen from Mr. Froude's papers in the Transactions of the Institute of Naval Architects, 1883 and 1886.

The curve showed conclusively that there was a slip ratio which corresponded to maximum efficiency. He (Mr. Hall-Brown) would not maintain that he had been right in giving the loss of efficiency due to an increase of 50 per cent. in the speed of the propeller at 17 per cent., but he would maintain that no increase could be made without some decrease in the efficiency of the propeller.

It was evident that to increase the speed of revolution, and at the same time to retain the same diameter of propeller as at first, would be to increase the work absorbed by the friction of the blades. And as the friction varied as the square of the speed (nearly) this would soon be a serious matter. To overcome this difficulty Mr. Patterson proposed to reduce the diameter of the propeller and to increase the slip ratio. There was a very practical objection to reducing the diameter, viz., the bluffness of the stern-lines of such a ship as "C." It must be borne in mind that it was cargo boats with which this paper dealt, and there were few engineers engaged in the manufacture of machinery for such boats who had not found from experience that a small propeller was an inefficient one. A theoretical objection—but no less he thought a very real one—was to be found in the fact that the smaller propeller required an increased slip ratio.

Mr. Barnaby's experiments gave for 800 I.H.P. and 9½ knots a propeller 18 feet in diameter. This implied that the present propeller

used for cargo boats was smaller than it should be, and therefore that the point of maximum efficiency had been already passed. In that case increased slip ratio must mean decreased efficiency.

But Mr. Patterson hoped to be recouped for any loss of propeller efficiency by a decrease in the augment of resistance caused by the action of the screw. He showed very clearly the effect of a reduction of 50 per cent. in the augment; but afterwards explained that he did not expect to get this, although, he said, experiment showed that he would get something. Mr. Froude's experiments, on the contrary, proved that variation in the dimensions of a propeller had no effect whatever upon the augment of resistance, which was a function of the thrust and dependent upon it. The amount of augment varied with the shape of the stern of the ship, and with the position of the propeller; but not with the size or form of the propeller.

As regards the propeller, then, he (Mr. Hall-Brown) claimed that to reduce the diameter, or to increase the speed of revolution, would be to decrease the efficiency. This was borne out in his experience, which might be said to have been practical experiments upon a very large number of actual propellers, the results of which had been analysed for the purpose of determining the best propeller. In spite of Mr. Patterson's remarks he still thought it a proof of the survival of the fittest, that the practice of the builders of cargo boat engines was very uniform as regards their propellers. The remainder of Mr. Patterson's remarks dealt with the design of engine, and were based upon Mr. Froude's estimate of the friction of a marine engine.

FROUDE'S ESTIMATE OF ENGINE FRICTION, ETC.

Horse-power absorbed in constant friction due to the dead-weight and tightness of the moving parts	·143 S.H.P.
Horse-power absorbed in friction due to the working load of the engine	·143 S.H.P.
Horse-power absorbed in air-pump resistances	·075 S.H.P.
Total	·361 S.H.P.

And as I.H.P. = 1·1 S.H.P.

Total engine resistances = ·328 I.H.P.

That was to say, leaving the propeller entirely out of the question, the engine was estimated to take nearly 33 per cent. of the I.H.P. to drive itself! He would not go into particulars as to how this extraordinary result was arrived at, but would merely remark that it was one which no engineer could consider correct.

He also wished to point out that the amount of friction placed against the proposed engine by Mr. Patterson was the enormous amount of 49·1 per cent. of the I.H.P. He (Mr. Hall-Brown) hoped to show that both of these estimates were much too high.

Our knowledge of engine friction depended chiefly upon experiments by Walther-Meunier & Keller, Hirn, and Thurston. One result of these experiments, and that which perhaps concerned them most as marine engineers, was, that it was conclusively shown that the friction of an engine was entirely independent of the load, and was constant, as long as the speed of revolution was maintained constant.

TEST OF A CORLISS ENGINE (SPEEDS CONSTANT) BY WALTHER-MEUNIER AND KELLER.*

Indicated horse-power ...	72·8	102·0	119·5	133·3	145·4	158·4
Horse-power absorbed by frictional resistance of engine and shaft	12·4	12·2	13·5	11·8	12·4	13·6

HIRN'S ENGINE (SPEEDS CONSTANT).*

Indicated horse-power	107	113	125	146	154
Horse-power by brake	95	102	114	134	143
Difference, or frictional resistance, H.P.	12	11	11	12	11

A short account of a paper by Dr. Thurston, giving his deductions on this subject of engine friction, was published in *Engineering* for January, 6th, 1888, as were some remarks by Professor Denton bearing out the same conclusions.

Bearing these deductions in mind, it was evident, that, if an engine were indicated while running unloaded at its normal speed the I.H.P. so obtained would be the frictional resistance of the engine.

This had been done, and two triple expansion engines experimented upon gave the following results:—

S.S. "CLEVELAND."†

Cylinders	21, 35, 57 in. diameter, 39 in. stroke.
Revolutions	63 per minute.
Vacuum	25 in.
Friction I.H.P.	linked, 47·59; throttled, 44·33.
Loaded I.H.P. at 63 revolutions ...	900.

So that the total engine resistances amounted to about 5 per cent. of the loaded I.H.P. This very small amount was doubtless due to the fact that the valves were all piston valves. The friction of the shafting was not included, but against this the circulating water had to be pumped through 450 feet of piping and against a head of 19·5 feet.

* From *The Steam Engine*, by D. K. Clarke.
† From *Engineering*, 26th February, 1886.

A test of a smaller engine was given in *Engineering* for June 11th, 1886:—

Cylinders	11, 16½, 30 in. diameter, 21 in. stroke.
Revolutions	140 per minute.
Friction I.H.P....	34.
Total I.H.P. loaded at 140 revolutions	300.

So that the total frictional and other resistances of this small engine only amounted to 11 per cent. of the total I.H.P. In this case all the shafting was connected.

These two examples sufficed to show that the total internal resistances of marine engines were much overstated by Froude, and he (Mr. Hall-Brown) proceeded to give an analysis, which, while agreeing with the values actually determined by Froude's experiments, and with the ratio $\frac{\text{I.H.P.}}{\text{E.H.P.}}$, differed materially from his analysis upon these vital points.

ANALYSIS.

Ship's true resistance	=	E.H.P.	
Augmentation due to action of screw ...	=	·4 E.H.P.	
Total friction of engines	=		·125 I.H.P.
Air-pump resistances	=		·025 I.H.P.
Loss at screw, due to friction, slip, etc., 62·5 per cent. efficiency	=		·319 I.H.P.

By addition—

$$\text{I.H.P.} = 1{\cdot}4 \text{ E.H.P.} + {\cdot}469 \text{ I.H.P.}$$

So that

$${\cdot}531 \text{ I.H.P.} = 1{\cdot}4 \text{ E.H.P.}$$

$$\therefore \text{ I.H.P.} = \frac{1{\cdot}4}{{\cdot}531} \text{ E.H.P.} = 2{\cdot}64 \text{ E.H.P.}$$

He (Mr. Hall-Brown) thought those figures were more in accordance with our knowledge of engine resistance, which he had estimated at the ample amount of 15 per cent. of the total I.H.P. These figures left less margin for manipulating the item of engine friction, but he did not intend to leave the matter even there.

Being anxious to arrive at the exact truth concerning the friction of single-acting engines, he had communicated with Mr. P. W. Willans, who had, he believed, a more intimate knowledge of this class of engine than any other man. Mr. Willans's answer was most emphatic and to the point. He said the friction of a single-acting engine was not greater than that of a double-acting engine, and gave instances of his own engines which indicated 200 horse-power, of which only 6 to 8 per cent. was absorbed in friction. This he (Mr. Hall-Brown) considered compared

favourably with any double-acting engine of equal power, and the figures could be implicitly relied upon. The friction running light was 7½ to 8 per cent. of the total power. These facts he considered were direct contradictions to the opinions of Mr. Patterson, and he thought it was evident that they need not fear that any gain due to the superior steam economy of the engine would be absorbed by an increase of frictional resistance.

Mr. Weighton had followed Mr. Patterson to a certain extent, in condemning the conclusion that 65 revolutions per minute should not be exceeded for the propeller of the ship "C." He pointed out very truly that every propeller was an experiment. He (Mr. Hall-Brown) thought that, that being the case, the builders of cargo boat engines had a very great number of experiments upon which to found their conclusions. In the case of his own firm he could say that these experiments were carefully watched, and the result of any departure carefully analysed. From these experiments the conclusions stated in the paper had been arrived at. The idea that a propeller 11½ feet in diameter, as proposed by Mr. Weighton, would be an economical one for the ship "C" seemed to him to be utterly absurd. He was of the opinion, that, builders of cargo engines knew a little more about the propellers with which they had to deal, than Mr. Weighton gave them credit for. Mr. Weighton had given a table (page 135) in which for comparison the size of the engine of No. 1 design was increased until the total mean pressure reduced to the low pressure cylinder was only 23½ lbs. per square inch. This Mr. Hall-Brown decidedly objected to. The expanded diagrams given were carefully worked out, and were as reliable as it was possible to make them. The water shown in these cards was 11·4 lbs. per indicated horse-power per hour. The consumption of water given in the paper was 13 lbs., and he thought this left an ample margin for jackets, initial condensation, etc.

As an example of the high economy to be obtained by properly designed single-acting engines he instanced the performance of Willans's high speed engines. One small triple expansion condensing engine of this type had given the remarkable result of 15·1 lbs. of water per horse-power per hour, using steam at 170 lbs. pressure. This was a splendid result and compared favourably with the largest sized triple expansion engines of the ordinary type. The reasons for this great economy he thought were the high speed of rotation, the efficient draining of the engine, and the fact that it was a single-acting engine. The engine proposed in the paper was designed to embody these advantages which

were the sources of economy in the Willans's engine, while representing a type suitable for indicating greater powers than his. He (Mr. Hall-Brown) therefore claimed that his estimate of the economy of these engines rested upon good grounds.

The engine which Mr. Weighton brought forward was an ordinary triple expansion engine, making 87½ revolutions per minute, and therefore by the preceding arguments must have an uneconomical propeller, and still further would have no claim to the economy expected from the engine proposed in the paper. Mr. Weighton had therefore not attempted a gain in fuel economy, but had been content to get weight economy at the sacrifice of propelling efficiency. The dead-weight so gained had been pointed out to be the lesser of the two ends aimed at, and if bought at the sacrifice of the efficiency of the propeller it was dearly bought.

Mr. Fothergill's remarks, showing as they did the trifling gain from increased dead-weight capacity, emphasised this.

Regarding the friction of the crank-shaft he would merely point out that in an ordinary double-acting engine this amounted to from 35 to 47 per cent. of the total engine friction. This was a shaft in which the direction of the load was constantly changing, and the friction compared very unfavourably with shafts revolving under a load always in the same direction, such as railway axles. This fact seemed to point to a reasonable expectation of a decrease in the friction in a single-acting engine, which resembles more the case of the railway axle, and this agreed with Mr. Willans's ideas on the subject. He did not anticipate any trouble from the absence of cushioning at the bottom of the stroke, and if such trouble were apprehended it would be overcome by design No. 2.

Regarding the limit of speed of revolution, this was determined by prudential considerations. It was evident that if the engine began to race and the governor shut off the steam, the whole pressure required to accelerate and retard the reciprocating masses would fall upon the connecting rod, bolts, etc.

In reply to Mr. Kilvington, he would say the reason for not adopting an 18 feet propeller, as given by Mr. Barnaby's rules, was that it would be apt to break the surface of the water as there was not sufficient draught. He had no doubt if properly covered it would be more efficient than the present propeller. For a proof of the practical accuracy of his method of calculating the pressures required to accelerate the reciprocating masses he begged to refer Mr. Kilvington to Kennedy on the *Mechanics of Machinery*.

Replying to Mr. Taylor, he showed jackets on all the cylinders be-

cause he believed them to be a source of economy. As the results of over fifty experiments with engines with and without jackets he understood that there had been a gain in every case; from 6 per cent. with badly designed jackets to 20 per cent. as a maximum. And after all, the jackets did not add so much to the weight of the engines, as by their use the size of the cylinders could be reduced. The reason for not jacketing the bottoms of the cylinders, was, that the water of condensation accumulated there, and if the surface was jacketed, this water would be re-evaporated, which was the very thing he (Mr. Hall-Brown) desired to prevent.

Mr. Fothergill's remarks were an agreeable change, inasmuch as he agreed with the writer of the paper as regarded the size and speed of the propeller. In his remarks upon the financial aspect of the question Mr. Fothergill dealt only with the gain due to increased dead-weight capacity. He considered evidently that the reduction in first cost and the gain from fuel economy were too problematical to be considered. In this he (Mr. Hall-Brown) could not agree with him. He had already tried to vindicate his claim to fuel economy, and would now place before them the whole financial aspect of the question, which was perhaps, after all, its most inviting one.

SAVING IN FIRST COST.

	£
Reduction in price of engine, allowing £510 for gearing and extra bearings	1,200
Reduction in price of boiler, due to decreased consumption of steam	426
Total	£1,626

SAVING IN WORKING EXPENSES ON AN INDIAN VOYAGE.

	£
Saving in bunkers 1·85 tons per day, say 60 days at 20s. ...	111
Increased freight carried, say 60 tons, at 20s.	60
Saving shown by Mr. Fothergill	43
Total	£214

That is about £3 10s. per day.

Regarding the question of jackets at sea, he (Mr. Hall-Brown) considered that by using the drains from the jackets to heat the feed-water in stages, and so making the jackets automatic in their action, all trouble to the engineers would be avoided, and the efficiency of the jackets would be maintained. The engine itself would require less attention than an ordinary engine, and as the bearings would run without knock until

Regarding the other speakers, he thought that as his reply was already too lengthy, perhaps they would find nearly all the points they had touched upon already replied to.

The only point really deserving of further treatment was that of suitable gearing. He (Mr. Hall-Brown) was sorry he had not had time to put his ideas regarding this upon paper, but was thoroughly confident that the problem presented no insuperable difficulties, and that a gear could be designed at once efficient, reliable, and practically noiseless, and one which would require no more attention than an ordinary thrust block.

He again begged to thank the meeting for the very kind way in which his paper had been received.

The PRESIDENT said, he thought the members would agree with him that Mr. Hall-Brown deserved their thanks for his admirable paper, one which had excited the greatest discussion he had heard within the walls of this Institution. He had to move that a hearty vote of thanks be accorded to Mr. Hall-Brown.

The vote of thanks was accorded by acclamation.

BOILER FURNACES.

By W. KILVINGTON and ALEX. TAYLOR.

[Read before the Institution on February 14th, 1890.]

Recently the thickness of the plates forming the furnaces of marine boilers has been increasing, but they have now got to a thickness beyond which a good many engineers hesitate to go, and therefore at this time a discussion of the question whether to go further or to stop will be both opportune and valuable. Not very many years ago a plate of $\frac{3}{8}$ inch was considered to be the thickest that could, or at any rate should be used for a furnace, and the supplement to Spon's *Dictionary of Engineering* says that plates of as great a thickness as $\frac{1}{2}$ an inch have been used; but this information is accompanied by a warning that serious results may be expected to follow. It is some time since any hesitation was felt in using $\frac{1}{2}$ inch plates, and at present very few engineers, the writers believe, object to plates $\frac{5}{8}$ inch thick, but they think that even this thickness may be greatly increased, and one of their chief objects in writing these short notes is to elicit the opinion and experience of the members of this Institution regarding the employment for high pressure marine boilers of what would be usually designated *thick* cylindrical furnaces.

The writers have advocated and employed from the very commencement of the introduction of high pressure triple expansion engines for marine purposes plain cylindrical furnaces—that is, furnaces without corrugations, rings, or change of form and section of any kind; and they are able to assert, after years of experience of their use, that such furnaces have given no trouble, and have been in every respect satisfactory up to a thickness of $\frac{3}{4}$ inch; and their confidence is such after this experience that they would not hesitate to still further increase the thickness if the circumstances of the case required it, and they now ask (and this is the essence of the whole question) if there is any proof and example of a case where a furnace has failed in any way merely on account of its thickness being too great?

This question is very important at this time and to this district, because here a large number—we believe the larger proportion of furnaces for boilers built on the Tyne—are now made of the "plain"

description, and because the Board of Trade demur to pass furnaces if they are made of a greater thickness than $\frac{5}{8}$ inch. The reason given by the Board of Trade for this is that they have no proof that the temperature in the thicker plates is not so much raised as to reduce the factor of safety. We think that this is not the case, because of the deductions to be drawn from experiments and formulæ to be presently referred to, but especially from the fact that we have had thicker furnaces in use for the last eight years at sea which have not changed in form, and are in every way effective to-day. The writers have knowledge and complete reports concerning furnaces in boilers of 160 lbs. pressure, made of about $\frac{3}{4}$ inch plate, which have now been worked continuously at sea from three to four years.

These furnaces are steel. If they had been iron, which is more subject to lamination, some of them probably would have failed from this cause. The reason for the failure of a laminated plate will be referred to further on.

The important points to investigate in connection with furnace plates would appear to be (1) the influence of the thickness on the transmission of heat through them, and (2) the effect of this thickness in raising the temperature of the interior of the plate. With regard to transmission of heat, it can be shown that the sum of the resistances at the two surfaces is so much more than the resistance to conduction through the body of the plate itself, that any thickness likely to be required to furnish strength due to compression or length can have little effect, and certainly would not be prohibitive or dangerous. The writers' experience of hundreds of, what would be called by some engineers, very thick furnaces, confirm this statement.

Rankine, in his work on the steam engine, gives the total thermal resistance of a plate

$$= (\sigma' + \sigma) + s\,x,$$

when $(\sigma' + \sigma)$ is the resistance of the two surfaces, and $s\,x$ the internal resistance of the plate to conduction of heat.

We have given

$$(\sigma' + \sigma) = \frac{1}{A\left\{1 + B\,(T' - T)\right\}}$$

when s = ·0043 for iron,
x = thickness in inches of plate,
A = 1·58 for dull metallic surfaces,
B = ·0037 „ „
and T′ and T = the temperatures of the fluids in contact with the two surfaces.

The writers propose to take $(T' - T) = 3{,}000$ degs., which is a much larger value than is likely to obtain in most marine boilers. But this will be referred to again.

If we compare, according to the above formulæ, the resistance of $\frac{5}{8}$ inch and $\frac{3}{4}$ inch plate, we find that the total resistances are as 550 : 555. That is to say, that by adding $\frac{1}{8}$th of an inch to the thickness of a $\frac{5}{8}$ inch plate the resistance it offers to the transmission of heat is only increased about 1 per cent. This shows how little mere thickness can have to do with this part of the question. But this was well known long ago, for Rankine says :—

"The external thermal resistance of the metal plates of boiler flues and tubes, and other apparatus used for heating and cooling fluids, is so much greater than the internal thermal resistance, that the latter is inappreciable in comparison; and consequently the nature and thickness of those plates has no appreciable effect on the rate of conduction through them."

And he also states that the results of experiments on evaporative results of actual boilers justifies the disregard of the effect of thickness on the rate of transfer of heat.

Mr. Isherwood made some experiments in 1867 on the transmission of heat through plates varying from $\frac{1}{8}$ inch to $\frac{3}{8}$ inch in thickness where one side of the plate was exposed to steam and the other to water, and he states that the thickness did not measurably influence the result. It is true that those plates are not very thick; but the variation in thickness is very considerable, and as far as the experiments go they afford a remarkable confirmation of what has just been stated. In the instance here given of course the plates were clean, that is, they had no "scale" on them, but it is probable that scale would affect the action of a thin plate in the same way as a thicker one, and apparently they are on a par in this respect. But heating and distortion due to scale and many other causes is often only local, that is over a small surface; and in case of any distortion of this kind a thick furnace would probably be much safer than a thin one, as the plate would be stiff enough to resist any dangerous change of form adjacent to the over-heated portion; besides the stiffness would check the distortion of the over-heated portion itself, owing to the support it would afford.

There can be little doubt that so far as the quantity of heat transmitted through the plate is concerned, the thickness can be still further increased, but the increased temperature of the plate itself due to this increase has yet to be considered. The writers at once admit that

this part of the subject, although much more important than the first, is not so clear, and the investigation of it much more difficult. Considerable thought has been bestowed, therefore, on this point, and the writers hope that at least an approximate determination of the temperature in the plate has been arrived at by the method now to be explained.

Above is a calculation of the total increase of resistance to transmission of heat for a $\frac{3}{4}$ inch as compared with a $\frac{5}{8}$ inch plate; but the writers think that the employment of a one inch plate would be quite safe for a boiler furnace, and the figures which follow refer therefore to a plate of this thickness. Taking the same formulæ as referred to in that calculation for 1 inch plate and 3,000 degs. as the difference of temperature between the fire in the furnaces and the water in the boiler—which we may call the *head* of temperature which is available to cause the flow of heat from the gases to the water—it is found that—

$\sigma' : s : \sigma :: 506 : 43 : 17 = 2{,}682° : 228° : 90°$ (sum $= 3{,}000°$).*

That is, that the head of temperature between the furnace gases and the inside surface of the furnace plate (that is the side exposed to the fire) is 2,682 degs.; and the difference of temperature between the inside and outside surface of the plate itself is 228 degs.; and the head of temperature between the outside of the plate and the water in the boiler is 90 degs. This calculation—as will be seen at once—entirely depends upon the assumption that the head of temperature will be proportionable to the resistance, which seems a reasonable assumption, and which it is believed cannot be far from the truth.

Taking this, it follows that the mean temperature of the plate, if we take the temperature of the water due to steam of 160 lbs. pressure, will be $370 + 90 + \frac{1}{2}(228) = 574$ degs., which would be the temperature somewhere about the middle of the thickness of the plate; but even if, as might be urged, the extreme inside temperature should be taken, then it is still only 688 degs.; and since, we believe, iron up to 600 degs. is not deteriorated in strength, it may be said that a plate of this thickness is within the limit of safety, as any decrease of strength at 688 degs., if it takes place at all, must be very small.

If this calculation is true, then the temperature of a furnace plate is much nearer the temperature of the water in the boiler than that of the heated gases in the furnace, due to the very great resistance at the

* In some experiments the writers made they found that the resistance to transfer of heat from a metal surface into air to be 30 to 35 times the resistance into water. Taking the least of these $\sigma' : \sigma$ are proportioned 30 : 1.

surface in contact with the light heated air and gases. The relative resistances here given are quite confirmed by observations on the reverse process of cooling heated metals in gases and in liquids.

The failure of a plate having a laminated portion in it is now readily explained, for that portion of the plate which is on the fireside being bounded on two surfaces by air or gas offers so much resistance to the escape of heat on the side furthest from the fire that the plate is heated to such an extent as to expand into an arched shape, forming what is called a "blister." This was an occurrence, unfortunately, only too frequent when iron plates were employed.

It may be surmised here, that it is probable steel plates will offer less internal resistance to the transmission of heat and will therefore be less raised in temperature, on account of their homogeneous nature, than was the case with iron plates, which had to some extent a fibre running across the direction of transmission of heat, and therefore most likely unfavourable to it.

In conclusion the writers wish to point out that they have in their calculations taken the temperature of the fire as high, or even higher than is likely to be got in a marine boiler furnace as at present worked. If we calculate the transmission of heat to the water in a boiler working at 160 lbs. pressure, and if the difference of the temperature at the furnace was 3,000 degs., and the temperature of the chimney gases 670 degs., we find that each square foot of heating surface transmits 16,650 units of heat per hour, and as each lb. of coal burnt, supposing a total value of 14,500 gives under these conditions of working 12,000 to the boiler, then for each foot of heating surface we should have to burn $\frac{16,650}{12,000} = 1{\cdot}38$ lbs. of coal, and as a common proportion of heating surface is 30 square feet per foot of grate, we should have to burn nearly 42 lbs. of fuel per foot of fire grate to maintain these temperatures. This is more than double the quantity almost ever burnt, therefore the case that has been taken is an extreme one. (See note on Rankine's formulæ on following page.)

Of course whatever reasons can be adduced for thickening up furnace plates applies equally to the plates of the combustion chambers and the importance of the whole subject, especially in view of the probable further increase of working pressure in marine practice, must be very great to an Institution like this, and therefore merits its earnest consideration.

NOTE.—Rankine gives an approximate formulæ for quantity in units of heat per hour transmitted to water in boiler $\frac{(T' - T)^2}{200}$. Let $T' - T = D$ difference of temperature, then mean value of

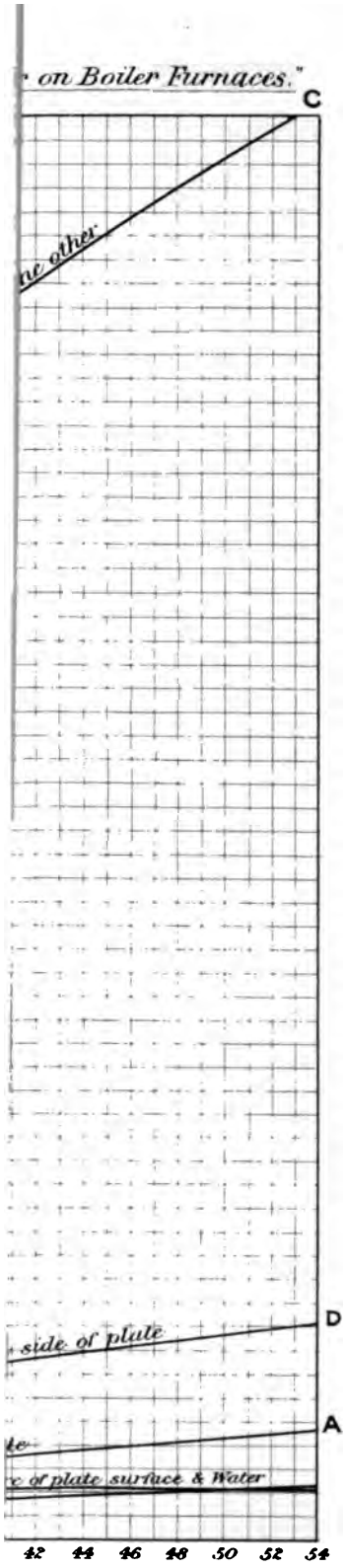
$$D^2 = \int_b^a \frac{D^2 \, d \, D}{a - b} = \tfrac{1}{3} \frac{a^3 - b^3}{a - b}$$

(which may be written for ease of calculation

$$\tfrac{1}{3} \left\{ a^2 + a\,b + b^2 \right\})$$

when D is taken between the values a and b; and this divided by 200 gives units of heat transmitted = 16,650 (about) in the case above.

And if E and e be the *elevations* of temperature of the fire and the funnel gases above atmospheric temperature, then each lb. of coal will give to the water $14{,}500 \frac{E - e}{E}$ units = in case under consideration 12,000 (about). It follows from this that $\frac{E - e}{E}$ = the efficiency of a boiler. The similarity of this equation *in form* to that for a heat engine is perhaps worth notice.



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NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

SIXTH SESSION, 1889-90.

PROCEEDINGS.

SIXTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON MONDAY EVENING, MARCH 10TH, 1890.

F. C. MARSHALL, ESQ., PRESIDENT IN THE CHAIR.

THE SECRETARY read the minutes of the preceding General Meeting, held in Sunderland, on February 14th, which were approved by the members present and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. H. Macoll and R. L. Weighton to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Dawe, Charles, Chief Engineer, H.M.S. "Pandora," Royal Navy.

Forster, William, c/o Messrs. Dixon, Robson & Co., 25, Mosley Street, Newcastle-on-Tyne.

Gardner, James, 75, Saville Street, South Shields.

Grimes, Thomas Benj., 30, Broughton Road, South Shields.

Hines, William, Chief Engineer, H.M.S. "Karrakatta," Royal Navy.

Hole, John W., Chief Engineer, H.M.S. "Whiting," Royal Navy.

McDougall, Neil, Managing Director British Steam Users' Insurance Society, Ld., 4 and 5, Victoria Buildings, Manchester.

ASSOCIATE.

Warren, Reuben Hynard, 151, Park Road, Newcastle-on-Tyne.

GRADUATES.

Brodin, Olof, 6, Park Terrace, South Shields.

Gilmour, William Laidlaw, c/o Messrs. R. Stephenson & Co., Ld., Hebburn-on-Tyne.

Lewis, Ernest Edward, 68, Crown Street, Newcastle-on-Tyne.

Orr, Reginald, 25, Croft Terrace, Jarrow-on-Tyne.

Wilkinson, Thomas, 14, West View Terrace, Lemington, Newcastle-on-Tyne.

THE GOLD MEDAL BEQUEST.

The PRESIDENT said, it would be within their recollection that the subject of medals for this Institution was talked about some little time ago. The money subscribed by three gentlemen in West Hartlepool (£274) had now been paid into the bank, and interest was accumulating for the purchase of those two medals, one for the best paper on Naval Architecture, and the other for Marine Engineering—one gold medal in each subject for each session. There could only be one feeling with regard to so handsome a contribution on the part of members whom they did not often see, who lived at a distance from them, and yet were so much interested in this Institution of the North-East Coast that they were willing to subscribe handsomely for the furtherance of its work. It afforded him very great pleasure to move—"That the best thanks of the members of this Institution be given to Mr. Christopher Furness, shipowner, Mr. Henry Withy and Mr. Wm. Richard Vick, shipbuilders, all of West Hartlepool," who were the donors of this handsome sum for the purpose already mentioned. He trusted it would be a stimulus to the members of the Institution, all of whom were free to compete for these medals in the papers they might contribute.

Mr. WM. BOYD said the matter had been thoroughly considered, and he had great pleasure in seconding the resolution.

The resolution was cordially adopted.

ANOTHER PRIZE FUND.

The PRESIDENT said that, in continuance of this prize movement shipbuilders on the Tyne and the Wear had, many of them, also handsomely contributed sums of £20 and upwards, to be devoted to the Graduates and other members of the Institution on other subjects than naval architecture and marine engineering, further particulars of which would be given at some future time.

The discussion upon Messrs. Kilvington and Taylor's paper on "Boiler Furnaces" was then proceeded with; after which, Mr. R. L. WEIGHTON read a paper on the Institution's Rule for the "Normal Indicated Horse-Power of Marine Engines and Boilers."

DISCUSSION ON MESSRS. KILVINGTON AND TAYLOR'S PAPER ON BOILER FURNACES.

The PRESIDENT said, they all had had time since last meeting for the consideration of the very interesting paper by Messrs. Kilvington and Taylor on "Boiler Furnaces." Before beginning the discussion he had to ask if the writers of the paper had anything to add in illustration of the paper, for he saw on the walls some diagrams no doubt of interest.

Mr. ALEX. TAYLOR said, that after reading their paper, they thought that it might be interesting to illustrate by diagram the formulæ given in *Rankine's Steam Engine.* The curves C and D, Plate XVI., do not give the exact difference mentioned in the paper, but it is not far off. The difference named in their paper was got by experiments, but they did not pretend to say their experiments were more reliable than the ordinary formulæ.

The PRESIDENT—I should like Mr. Taylor to inform us whether lines A and B, Plate XVI., represent the mean temperature, or rather their space represent the mean temperature we would have in precisely similar conditions in the boiler, having a half-inch plate and one inch plate?

Mr. TAYLOR—Yes; the straight line A represents the head of temperature for an inch plate, and B that for half an inch plate.

The PRESIDENT—What I want to know is—What, according to your researches, is the mean temperature of the inch plate as compared with the half-inch plate under precisely similar conditions? Am I to understand, or is the meeting to understand, that the mean temperature of the plate—not the difference of the temperature of one side or the other—the mean temperature of the plate of an inch thick is double the mean temperature of a half-inch plate?

Mr. TAYLOR thought he might answer the President as follows:—Suppose an inch plate transmitting 40,000 units of heat per square foot of surface, and that the water temperature was 370 degs., then by the diagram there would be a head of temperature equal to about 100 degs. between the plate and water, and between the two sides of the plate a head of 180 degs.; with this information we find the mean temperature of the plate to be $370 + 100 + \frac{180}{2} = 560$ degs., but if the plate had been only half an inch thick there would have been a head of only 90

degs. in the plate, so that instead of having 560 degs. they would have only 515 degs. mean temperature of the plate. He thought that was what the President wished to know.

The PRESIDENT—I think I understand you. Mr. Kilvington had been good enough, in addition to his paper, to write to Mr. Parker of Lloyd's, to obtain his opinion on the subject, which he had kindly brought before them. Mr. Parker had written a letter, and with their sanction he would read it as part of the discussion.

COMMUNICATION FROM MR. WILLIAM PARKER, ENGINEER IN CHIEF TO LLOYD'S REGISTER OF BRITISH AND FOREIGN SHIPPING.

11*th February*, 1890.

DEAR SIR,—I am much obliged to you for your memo. of the 9th inst., enclosing a copy of the paper which you and Mr. Taylor are about to read before the North-East Coast Institution on "Boiler Furnaces." It is a most interesting subject, and one to which I have given considerable attention of late; and as you ask my opinion I may state that, speaking as an engineer who would have to be responsible for the efficient working of furnaces at sea, and not as a surveyor to this society, I would not use thick plates. I think it is bad engineering to make a furnace, a tube plate, or any other part of a boiler, which is exposed to the direct action of flame, stiff and rigid by mere quantity of metal. The required strength should, in my opinion, be obtained by staying or special design rather than by unduly increasing the thickness of the plates.

I note from the paper that your conclusion that the thickness of plate has comparatively very slight influence upon the rate of heat transmission is based upon a statement of Rankine, and upon some experiments made by Mr. Isherwood in 1867. I think that further evidence is desirable before this can be accepted as established, as general experience shows that steam is more rapidly raised in boilers having the heating surfaces of thin plates than when the plates are thicker. I am inclined to doubt the accuracy in practice of the result arrived at by applying Rankine's formula, viz., that the resistance to the transmission of heat through a $\frac{3}{4}$ inch plate would only be one per cent. greater than through a $\frac{5}{8}$ inch plate. Some further experiments of a practical character to determine this question would be of great value. There came under my notice recently some new boilers made on the East Coast in which the furnace and tube plates were exceptionally thick. After having been at work a short time the seams where the furnace and tube

plates overlap were drawn and sprung to such an extent that the vessel had to be laid up for expensive repairs, and this is only one case of many that I could mention.

I am inclined to agree with the Board of Trade in thinking that we have no proof that the temperature in the thicker plates is not so much raised by the greater resistance as to reduce the factor of safety, and your statement that some thick furnaces have worked satisfactorily for eight years is not sufficient to disprove this; it merely shows that no collapse has hitherto taken place in those cases, and this immunity, I would submit, may be due to the careful treatment of the furnaces securing their safety in spite of a reduction in the factor of safety.

I may add that when considering the subject a few weeks ago I wrote to some of the leading boilermaking firms, and also to the superintending engineers of the principal mail lines, who are responsible for the efficient working of the boilers, requesting an expression of their views on the thickness of furnace plates. The replies were interesting and in many cases conflicting, but not one of the superintendents advocated thick plates, whilst the views of engine builders, even those on the East Coast, keen competitors with yourselves, differ widely one from the other.

I shall be glad to read the discussion, and regret that I shall not be able to get down to Newcastle to join it, but you are at liberty to hand this letter to the President for him to read to the meeting should he think fit.

I am, yours faithfully,

WILLIAM PARKER.

W. Kilvington, Esq.,
North-Eastern Marine Engineering Co., Ltd.

The PRESIDENT thought they would all be obliged to Mr. Parker for opening a discussion of this practical character. The discussion was now open to the meeting. He should claim the liberty of making a few observations at the close; but at the moment he would be glad to hear what the members had got to say. Allow him to call their attention to one special remark their friends (Messrs. Kilvington and Taylor) made at the beginning of their paper, that one of their chief objects in writing these short notes was to elicit the opinion and experience of the members of this Institution. He hoped, therefore, there would be no hesitation in expressing the views of the meeting.

Mr. J. F. WALLIKER said that they must all feel extremely obliged to the writers for bringing before the Institution such an able and valuable

paper, and he trusted that it would elicit, as it deserved, a good and thorough discussion. When the subject of thick plain *versus* improved furnaces was first introduced he was much inclined to favour the former; it had certainly many good points, and it appeared to have a fair immunity from accident, but at the same time he must say that more recent experience had shown him where serious trouble had occurred, and where they might look for similar results in the future. A short time ago he had to examine a high pressure boiler, where two of the furnaces were distorted through overheating, and it became a matter of moment to the shipowner when it was found that the thickness and rigidity of the plates prevented them being put back into their original shape—as a matter of fact they were fitted with dog stays, and are so running now. Now, when thick plain furnaces go like this, and he could cite other similar cases, they have either to be cut out or strengthened in the manner described, and he considered that this meant a very serious depreciation of the boiler—it decreased its strength and accessibility, and also made it more liable to harbour dirt, and more difficult to clean. The improved furnaces did not suffer from this defect, as they were easily set back when found deflected. He did not consider that their experience with plain thick furnaces warranted them in increasing the thickness without further and exhaustive experiments being made.

Mr. William Boyd did not think he had anything to say which would throw much light upon this subject, but it was a matter which was of very great interest to all manufacturing engineers, to use the words of Mr. Parker's letter—"even those on the North-East Coast." Speaking as a manufacturer on the North-East Coast, certainly "the economy of production" (a favourite phrase of his) did enter very materially into the consideration of these questions, and if it could be satisfactorily established that a plain furnace of any given thickness was equally safe and equally efficient as a means of conveying the heat from the fire to the water inside the boiler as those patent furnaces, well, he for one was content, and to be ranked amongst "even the manufacturers of the North-East Coast," and willing to adopt such an "economy of production." As to whether that was so or not, seemed to be a very disputed question, and one of those questions, it so happened, in which there was a singular absence of any experimental research upon which arguments could be based; and of course it was, comparatively speaking, an easy thing to meet such a scientific statement and calculations as had been brought before them by the authors of this paper, by an *ex parte* statement that such and such things were not regarded by

manufacturers or superintendent engineers as being efficient or safe. He did not think that really was much of an argument. Mr. Parker said that certain gentlemen whom he had consulted did not advocate thick plates, and that as those replies were in a great measure from persons in charge of the boilers, they formed a very strong argument, as it were, against it. He (Mr. Boyd) could not say that struck him as a very strong argument against the adoption of thicker plates, because if the use and adoption of a thicker plate was based upon sound, scientific principles, the same necessity would exist for taking care of corrugated furnaces as of plain furnaces, and if equal care was bestowed in each case the plain furnaces would be as efficient and last as long as corrugated furnaces. He could only bring to bear an ordinary common-sense view upon these questions. He did not propose to go into the interesting diagrams Mr. Taylor had exhibited, but it so happened that in a recent case in which Mr. Taylor was also associated, he (Mr. Boyd) was satisfied that after all a certain rule of thumb was made use of. His firm were anxious in a certain instance to introduce a furnace of a thicker plate than was compatible with the Board of Trade rules, and as a compromise a "stiffening" ring was introduced half way along the furnace and the thickness of the plate was reduced to five-eighths. He meant to say that this particular case (which to a certain extent had been one of the instances that gave rise to this paper) showed the necessity, he thought, not only of this paper but of carrying the matter further, for it showed that the rules which were being acted upon both by Lloyd's and the Board of Trade (if their representatives would excuse him saying so) were entirely empirical and based merely upon what they believed to be safe. Mr. Parker had made use of an expression in his letter which had made him again think of an idea that had occurred to him in reading this paper. He did not know what their President or future President would have to say to it, but there was, or ought to be, a certain balance to the credit of the Institution at the end of the present year; and as it was, in his opinion, undoubtedly the case that experiments might be made, and he thought at a very moderate cost, which would at any rate throw some light upon this subject, he ventured to think that it would not be beyond the functions of this Institution if some portion of that surplus which they might find in their possession at the end of the year were devoted to experiments on a small scale, in endeavouring to ascertain the practical effect of increasing the thickness of plates, as to the passage of heat from the fireside to the water on the other side. He did not know if that idea would

commend itself to those in authority, he threw it out for what it was worth. If it could be done on a small scale as he thought it might be done, he thought it would be one of those ways in which the Institution might do good service to the engineering profession of the country.

Mr. J. C. SPENCE said, the paper under discussion treated of the influence of thickness on the transmission of heat through furnace plates. Mr. Boyd had raised the equally important question as to the thickness required for strength, referring to the rules now in use as empirical and unsuitable to modern requirements. The remarks that he had to offer were in confirmation of those made by Mr. Boyd. Empirical rules, when based on an extended and varied practice, are frequently the best guides an engineer can have in his work: but in the matter of the strength of furnaces, our rules are not based upon practice, but our practice on our rules. The rules still in use were formulated by Sir William Fairbairn, and founded on a series of experiments made by him thirty-two years ago. A brief analysis of these experiments will show clearly how unsuitable they are to modern marine work. Out of 40 experiments on the resistance of tubes to collapsing, 35 were made with tubes only ·043 inch thick, the diameter varying from 4 inches to 12 inches, the length from 30 inches to 60 inches. From this series it was inferred that the pressure a tube could stand varied inversely as its diameter and its length, because the pressure multiplied by the length and by the diameter came out approximately a constant. This approximation is by no means close, ranging from 650 to 1,080, with an average of 820 units, the experiments varying so greatly among themselves that a modern experimenter would be more likely to reject the whole lot than to deduce a general law from them. In the formula now used for the strength of plain furnaces, namely $\left(\frac{P \times L \times D}{T^2} = \text{constant}\right)$ the first assumption, that $P \times L \times D$ is a constant, does not therefore rest on a satisfactory basis. It is highly improbable in itself, and is not supported by reliable experiments. But the second assumption, that the strength of tubes varies as the square of their thickness, is still more unsatisfactory. The way it was arrived at was this:—Having averaged the 35 experiments with tubes ·043 inch thick, the result was compared with—

1 experiment on a tube ·125 inch thick,
1 „ „ ·14 „ „
1 „ „ ·25 „ „

And from these was deduced the law that strength varied as $T^{2\cdot19}$, or approximately as the square of the thickness. The method of making

this comparison is so unreliable that by a different manipulation of the same experiments the index of T may be proved to be 1·2, instead of 2·19; and by picking out different experiments from the same series we could get almost any index we like. Fairbairn's experiments, taken as a whole, afford some evidence that with very thin tubes the strength increases faster than the thickness, and strong evidence that long tubes are weaker than short ones. At the time when they were made they were of great service in disproving the theory then held, that the strength of tubes was independent of their length—a plausible error still held (and on exactly the same grounds) with regard to tubes subject to internal pressure. They were also of great practical value in showing how the long flues of Lancashire boilers could be greatly strengthened by the introduction of stiffening rings. But they form an absurdly insufficient basis for regulating modern practice in marine boilers, seeing that the material used and the actual and relative sizes differ so widely from the material and sizes experimented on. Under these circumstances he considered the Institution could not perform a greater service to engineering than by carrying out the experiments suggested by Mr. Boyd, and if this were done we ought not to be content with any empirical formula. Dealing with such simple factors a rational theory is possible if properly sought for. And this is certain, that a true theory of the strength of furnaces will apply equally to the strength of shells; the difference between the compressive and tensile strength of steel will not affect the form of the theory, only the constants used. The only essential difference between the two cases is that tubes subject to external pressure are in a state of unstable equilibrium, and therefore collapse totally whenever the strain at one point exceeds the strength at that point, while those subject to internal pressure are in a state of stable equilibrium, and do not rupture until the mean strain exceeds the strength. At present we are working quite in the dark. In assuming that a $\frac{5}{4}$ inch plate is four times as strong as a $\frac{3}{8}$ inch plate—a palpably untrue assumption, we may be working with a much lower factor of safety than we think; or, on the other hand, if, as is more likely, the comparatively short tubes we use do not vary in strength inversely as their length, but only as some function of the length, we may be using a much greater factor of safety than we suppose. At all events even if later experiment confirmed our present theories, which is hardly credible, it is evident that they need this confirmation.

Mr. J. Wallau said he must apologise for not having read the paper or heard it read, but there were a few simple matters in connection with it

which he thought he might as well mention. Mr. Spence had been ill-using their rules very severely; but he thought the tests which they had of their boilers—of which perhaps 20,000 or more were in existence—pretty well confirmed the rules. Besides, there had been experiments made by the Board of Trade and others, which also to some extent confirmed them. It might be that the strength of furnaces did not vary exactly as the square of the thickness of the plates, but varied as a slightly higher power of the thickness; but that was not of much importance, as the thickness generally was only between three-eighths and three-fourths of an inch. A further fact was that they tested the boilers to double the working pressure, and they stood the tests not so abundantly, as to show a very large margin of strength. On the contrary the tests sometimes sprung the furnaces and put them slightly out of shape. No doubt if very careful experiments were made perhaps the rule would be modified, but he did not think the rule would be upset altogether. Of course the rule was empirical, for when they came to very short surfaces of furnaces they left the square out and took the thickness only. If the rule was a perfect rule it would apply to all cases; but two rules being necessary, showed that they were empirical. Nevertheless, taking the two rules together, the one containing the square of the thickness and the other the simple thickness, they got a very reliable result. When accurate experiments were made he might, perhaps, after all, be wrong, and Mr. Spence might be right. What he would say was, that furnaces were very liable to give trouble by collapsing when they got dirty, and with all their care they could not have a sufficient number of good men. They had unavoidably some second-rate men, and even third-rate ones; the consequence was the furnaces were not always kept sufficiently clean, and in this way furnaces had failed for many years, when the barrel was only $\frac{5}{16}$th of an inch thick, with 10 lbs. or 15 lbs. pressure upon it. This was really the difficulty of the present furnace, and was only got over by doing away with the ordinary system of boilers, which had been adopted for a good many years now, and would be upset some day on account of the always increasing steam pressure, which means increasing weights. With the present system the plain furnace required extra thickness, and this extra thickness added to the difficulty when they came to forced draught, which increased the temperature in the furnace so much that the danger of injuring the furnace, especially if they were any way neglected, was very great; and of course if it occurred, as was mentioned in Mr. Parker's letter, that a thick furnace plate was riveted on to a thick tube plate, and the thick plates as well as rivets exposed to a great heat in the case

of forced draught, then he would certainly be inclined to use thinner plates and obviate the rivets by welding the tube plate on to the furnace. Another way to evade this difficulty was to get the furnace much longer than the fire, so as to have the fire at the front end of the furnace. Whenever they had a long fire and short furnace the rivets at the bottom of the tube plate suffered, but with a short fire and a long furnace this trouble was avoided—the run of the fire was then sufficient to take out the extreme heat which existed in the furnace only, and not within the rest of the boiler. His own belief was that the rising generation had to set to work to scheme a new boiler. The present boiler was gradually wearing out on account of the ever-increasing pressure; and although a number of boilers of different types have been schemed, none of the new types have so far been thoroughly successful for sea-going steamers.

Mr. JAMES DYKES said, much mischief was done to plain furnaces with triple expansion engines, owing to engineers raising steam too rapidly, often causing considerable leakage. He had plain furnaces about seven years old, working at 150 lbs. pressure, and never had the slightest trouble with them. Lately, however, with plain furnaces at 160 lbs. pressure, he had had a good deal of trouble—the principal cause of this being through the engineer raising steam too rapidly, and omitting to use the blow-off cock when raising steam. He thought the great fault of plain furnaces as now fitted to high pressure boilers is the abruptness of the flanging. He found very little trouble with scale adhering to the plain furnaces, and as far as pitting and scale were concerned he would certainly recommend plain furnaces. He would like to see furnaces tried 1 inch thick, for he thought they would be less liable to collapse than corrugated furnaces, as these accumulated and kept the scale, thus preventing the water from gaining access to the plate. He did not think there would be any trouble with the heat radiating. He had corrugated furnaces four and a half years old, and had no end of trouble with scale adhering to them. The inch plate, he thought, would not collapse, and he would much like to hear of the experiment being tried.

Mr. C. J. SEAMAN said he would like to suggest, if any experiments were made with furnace plates an inch thick, that special attention should be given as to the difference of expansion on the inside and outside. He thought that perhaps the failure which he believed Mr. Parker referred to in his letter was due to that cause. He would be glad if the writers of the paper, or any other gentleman could give them any information as to this expansion and contraction.

Mr. JAMES PATTERSON did not come with the intention of making

any remarks. He thought they should have had a great deal said by advocates of thin furnaces. There was no doubt that, although this *was* the North-East Coast, they would all concur with the writers of the paper that a thin furnace was better than a thick one. The question raised in the paper appeared to him to be—why do we not use thicker furnaces than we do? Not because the furnaces would be better thicker, but with a view to obtaining larger diameter and higher pressure with any given type of furnace. The reason for not using thicker furnaces than they did at present appeared to him to be because their ideas of the behaviour of furnaces were very largely built up on a past experience of—firstly, furnaces made of iron plates more or less laminated or fibrous in structure, which material should behave very differently in the transmission of heat from a homogeneous metal; secondly, on the behaviour of furnaces badly treated at sea, furnaces so used that dirt had been allowed to accumulate on the top and so prevent the free transmission of heat to the water. He thought there was also a third thing which had determined them not to go further with the thickness of plates than they did at present, and that was the very plausible but erroneous idea that if they doubled the thickness of the plates the resistance to the transmission of heat would be doubled. He thought they were very much indebted to the writers of the paper for bringing to them clearly that this was not the case, that experiment had proved it not to be the case, and that the correct rule for determining how the resistance varied with the thickness of plate was something very different from varying directly as the thickness, and that the greatest resistance offered to the transmission of heat from the fire to the water was at entering and leaving the plate, and the passage of the heat through the plate was insignificant as compared with the others, and it was this small portion of the total resistance which alone was affected by increased thickness of plate. He thought they had brought this before them very clearly, and it behoved anyone who believed that the limit of thickness that was safe had been reached to give some reason for so thinking. All the arguments showed that they had not reached that yet, and he quite agreed that a three-quarter inch plate with a homogeneous metal was perfectly safe, but if dirt collected on the crown of the furnace it would be dangerous; but if that happened with the thin furnaces it would be also dangerous. Thin furnaces had been known to come down from the dirt and oil that collected. This was the great danger to which furnaces were exposed, and the simpler they could make the form of the furnace to prevent this collection of oil or solid matter the better. It was said that thick furnaces caused trouble at the joints

where there were two thicknesses or more of plate on account of the great aggregate thickness of the joint, but that had nothing to do with the thickness of the furnace. He saw no reason why with a thick furnace plate joints should not be worked down to what was considered a minimum of thickness consistent with safety. Trouble at the joints had nothing to do with the question.

Mr. J. T. MILTON said, Mr. Patterson had made one remark from which he begged slightly to differ. He said that the trouble caused at the junctions of the furnace plates was due to the thickness of the plate at the joints. He thought in many cases it was not due to that at all, for in many cases the trouble was not at the joints exposed to heat, but at the joints furthest from the heat. If that was so it showed it must be due to some other cause, and that was probably the expansion of the plate. He (Mr. Milton) was not quite clear as to Mr. Taylor's number of degrees, but thought he showed that if we doubled the thickness of the plate, we must at the same time double the increase of its temperature over that of the water. He thought, that although he made out the extra resistance offered to the flow of heat was very little, yet the resulting difference of temperature might double our trouble if the trouble was due to the influence of expansion. The absolute amount of expansion was proportional to the difference of temperature between the furnace plate and the water. If we doubled this difference we doubled the increase of length of that part and doubled the cause of leakage. Even with the present thicknesses of furnaces, say half an inch, in many cases the increase of temperature in the plate, although the authors showed it to be small, brought quite as much strain on the joints as the ductility of the material would bear; if we went to greater thicknesses then we should get more expansion, and that would produce leakage, which might not be a source of danger, but would be a source of inconvenience. The mere fact mentioned by Mr. Walliker that a good many thick furnaces had collapsed did not condemn them. They knew that corrugated furnaces had in some instances collapsed, but when they did they never heard it was because they were too thick, but always because they had been short of water, or had become coated with scale or dirt. He believed, in some of the largest steamers afloat, the furnaces could not be kept tight owing to expansion. If that was so, and we go in for thick furnaces, we shall have to modify the ends of furnaces, so as to make them less rigid and more elastic longitudinally.

The PRESIDENT thought they had had an extremely interesting discussion, and that they were very much indebted to the writers of the

[illegible] He thought [illegible] read the [illegible] of [illegible] very little [illegible] submit [illegible] with the [illegible] Mr. Milton had [illegible] He believed it was [illegible] "Terrible" [illegible] of those [illegible] furnaces knew [illegible] right. [illegible] introduction [illegible] He had asked [illegible] Plate XVII. [illegible] that at [illegible] through each of the [illegible] of the form that [illegible] the fire box and [illegible] plates relatively to [illegible] impossible to keep [illegible] when he [illegible] plates. [illegible] the last [illegible] legs and the [illegible]

[illegible] Mr. [illegible] your [illegible] temperature [illegible] legs.

[illegible] of the [illegible] they had then [illegible] Mr. [illegible] inch or [illegible] the width of the plates composing [illegible] a quarter of an [illegible] to go. [illegible] the danger. [illegible] the construction of their boilers. He also [illegible] were turned by over-

staying than by under-staying. He was extremely sorry to have to say that their friends of Lloyd's, the Board of Trade, and the Admiralty were "all tarred with the same brush." They saw the difficulty in expansion, it was essential that the boilers themselves should have room, as the boilermakers had it, "to breathe." They had a certain distance from the furnace to the lowest row of tubes, and with a strong joint at this point there was very little elasticity or breathing space. In the matter of staying it should be borne in mind that the boiler itself could never be higher in temperature than that of the water, and must not be expected to expand as much as the furnace, which had got 100 degs. more heat than the water. Now, in this boiler (Plate XVII.) they had great trouble with the joints immediately above the centre furnace, the joints were sprung by the expansion and leaked. They took out the long stays running from end to end and fitted instead two dog stays, as shown, and they had no further trouble, showing that the difference of temperature was entirely overlooked by Lloyd's and the Board of Trade who insisted upon having these through stays. The only reason for his rising was to call attention to the difference of expansion between the thick furnace and the thin furnace, and the evils introduced thereby; and he could only hope that some means would be taken to induce their friends at Lloyd's and everyone of them as draughtsmen and engineers to be very careful in their designing, and allow their plates a little more "breathing space" than they generally had. Their boilers would then be more durable and give less trouble with leaky joints and leaky tubes.

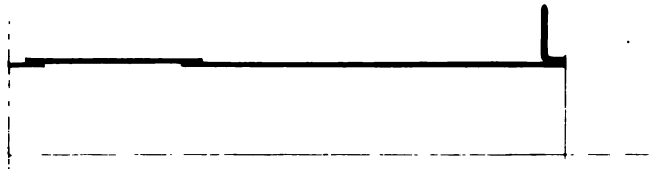
Mr. Alexander Taylor, in reply to the discussion, said, there could be no doubt that thick plates in themselves were not as good as thin plates for transmission of heat. Mr. Parker writes that he would not use thick plates, but they (the writers) were quite satisfied that $\frac{3}{4}$ inch plates could be safely used in a furnace, and daily experience proved this was so. Mr. Parker doubts that the difference of resistance to transmission through $\frac{5}{8}$ and $\frac{3}{4}$ inch plates was not more than one per cent., but thinks it must be greater. The writers are supported both by experiment and formulæ in the statement that the difference in resistance is not more than stated in the paper. Mr. Parker states also that thick plates cause leakage at the seams exposed to the fire. This he (Mr. Taylor) would refer to later on.

It had been said that the ordinary boiler was "worked out" and "on its back." Is it not a positive fact that we have increased the working pressure and thickness of plate and pitch of the stays, giving "more

breathing space," as the President put it, *followed by marked lengthening of the life of the boiler?* When he (Mr. Taylor) first came into the trade, five years was considered not an unusually short life for a boiler, now they are not at all astonished at fifteen years' life. He thought a great deal of that lengthening of life was due to increased thickness of plate. Mr. Parker said eight years' experience with thick plates proves nothing, but the speaker was not disposed to throw away eight years' experience, and thought it stood for a great deal. He remembered that in 1878 they put $\frac{5}{8}$ inch steel furnaces into a boiler, and that boiler was running now, and, as far as he knew, not a tool of any kind had been put upon the furnaces, except cleaning tools. This was a case of a boiler twelve years old with $\frac{5}{8}$ inch furnaces; these furnace crown plates were flanged up at the back and welded to their tube plates, and had given no trouble. After this paper was written he drilled one hole through the furnace crown right above the bridge, and another about a foot from the front of the boiler, and found the plates fully $\frac{5}{8}$ inch thick; this proved that twelve years' work did not reduce the furnace crown thickness. They were told that thick tube plates caused tubes to leak. His experience was that to-day tubes lasted longer than ever they did. They did not think anything now a days of tubes being seven or ten years old. At one time it was a wonderful tube that lasted longer than four years. So, notwithstanding all the stated leakage and the trouble with these thick plates the life of the boilers and the life of the tubes were lengthened, and there were not as many repairing shops living out of the marine boiler as in former days.

Mr. Walliker said that one of the writers knew something about the collapse of a plain furnace. The furnace Mr. Walliker referred to was $\frac{21}{32}$ thick, eight years old, and *iron plates*. One furnace was considerably laminated, and would ultimately probably have to be taken out, on account of the lamination and not because of the thickness causing it to collapse. He was quite sure they all knew that other than plain furnaces had been laminated and had come down. He was quite convinced that the thicker they made plates in the combustion chambers, the better for the boiler and its life, they would have fewer stays to leak, and in every way a much more satisfactory boiler. Give him by all means thick plates and few stays. He admitted that forced draught put greater work upon the plate; of course the temperature was increased in the furnace by it, but don't let them forget this fact, that they, as writers of this paper, took the ordinary boiler under ordinary conditions. Very likely inch plates would do very well with certain forced draught,

naces."



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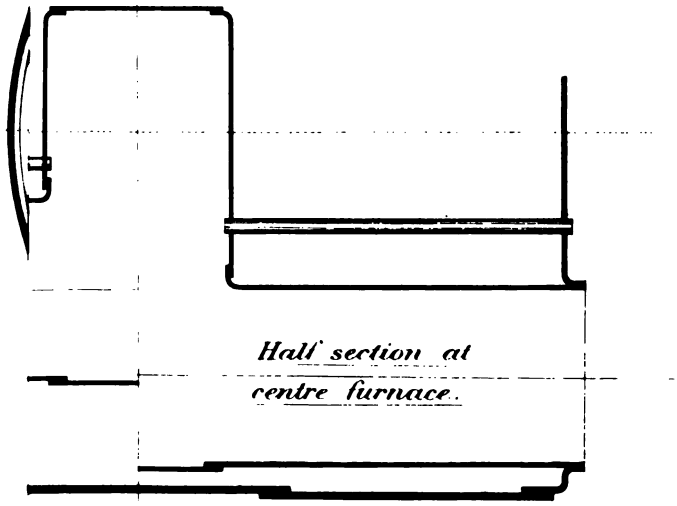

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but they might not do under all conditions. With one double-ended boiler, fitted with patent furnaces, he had considerable trouble to keep the back seams (which were in the furnace) tight, but after shortening the grate about 30 per cent. he had no further trouble, proving that thin as well as thick plate seams can give trouble in the fire. The President mentioned one case where they had considerable difficulty with leakage from the furnace back seams, but after altering the stays between the furnace and tubes the leakage ceased, and immediately the seams were tight. Was that any reason why the thickness of the plates should be condemned? Did it not show that there was a fault in the design? This may also apply to Mr. Parker's case of leaky seams. He did not think thick plates should be condemned for these defective designs, whether through Board of Trade, Lloyd's, or any other rules.

Mr. W. KILVINGTON observed that Mr. Taylor had really answered so fully that he had left him little to say. With regard to what Mr. Parker said he would only emphasise the line of argument taken up by Mr. Taylor, and said he knew of furnaces worked since 1883 close upon $\frac{3}{4}$ inch thick, and they had given absolutely no trouble whatever. Mr. Walliker instanced a case of an accident—he could call it nothing else—to a furnace. He submitted it did not show anything one way or the other. They did not say the plain furnace was a perfect furnace, nor could they guarantee it free from accident. Mr. Wallau "hit the nail on the head" when he said furnaces required to be kept clean, for probably the resistance due to a very small amount of scale was very much more than due to the whole thickness of the plate, even were it made 1 inch thick. With regard to the difference of temperature due to the increase of thickness from $\frac{1}{2}$ inch to 1 inch, we find that the mean temperatures will be 518 and 574 respectively, or an increase of about 10 per cent.; and the structure of a boiler must be very rigid indeed if this will make the difference between tightness and excessive leaking. He was very much obliged to Mr. Dykes, who had experience of the plain furnace, coming and saying that they had given him every satisfaction, after extended use. It was weighty evidence against the opinion of men who so far up to the present had not even tried them.

The PRESIDENT was sure there would only be one sentiment in the feeling of everyone, and that was of gratitude to Messrs. Kilvington and Taylor for the interesting paper brought before them. He could only ask the meeting to accord to them their hearty thanks in the usual manner.

The resolution was passed by acclamation.

NORMAL INDICATED HORSE-POWER OF MARINE ENGINES AND BOILERS.

By R. L. WEIGHTON, M.A., Vice-President.

[Read before the Institution on March 10th, 1890.]

The members of this Institution have had no opportunity as yet of discussing the rule for N.I.H.P., published in the Council's Report at the end of session 1888. (See Appendix A, page 196.*)

This report has been circulated freely amongst the technical institutions, and other bodies and individuals in the country who were considered interested in the matter. Some of these have expressed their opinions upon the merits of the rule, which in several cases have been favourable and in others unfavourable. In many cases the scope and intention of the rule has been totally misunderstood. This has doubtless been largely due to the fact that the report appeared in a very condensed form; and in bringing the subject before the Institution at the request of the Council, the writer hopes that, by entering at greater length than was possible or desirable within the confines of a report, into an exposition of the principles upon which the rule is based, such misapprehensions may be corrected, and future ones obviated. He undertakes this the more readily because he believes that, if properly understood, this rule will prove of great value not only to shipowners, underwriters, and non-technical men generally, but that it may also be found of very considerable value in the practice of marine engineers themselves.

In proceeding, it may be well to first deal with certain questions which naturally arise on the threshold of the subject, viz., for what purpose is any rule required? Is there any *need* for a rule to take the place of the now obsolete nominal horse-power? And if there is a need, what is it intended to represent, and for what is it to be used? The first two of these questions might be answered by asking others:—Is there any need to know the value of any article? Is there any need to know how far any article is capable of fulfilling the purpose for which it is intended? Is there any need to have some reliable standard by which to *measure* the capacity of any machine for fulfilling the purpose for which

* This Report was published as an Appendix to Volume IV. of the Transactions of the Institution.

it was designed and constructed? In a word, is there any need to know the comparative values of different articles to their users? We presume such questions can only be answered in the affirmative. There *is* a need —a very great need—to be able to *estimate* the comparative *values* of different engines and boilers, and different combinations of engines and boilers. The answers to the second two questions will be given as we proceed.

Marine machinery may be said to have two kinds of value—(1) value to the owner, and (2) cost to the builder. These two values are not synonymous, and do not necessarily run parallel with each other for all sizes of even one type of machinery. It is the first kind of value with which we are chiefly concerned, but the relation of the second to the first will also be touched upon briefly.

I.—Value to the Shipowner or User.

It is obvious that the ultimate and only real *value* or *worth* of any machine is its value or worth to its owner or user. In proportion as it fulfils the purpose for which its owner intends it, will its value be measured. This kind of value, like other commercial values, fluctuates much owing to varying circumstances, and it may be impossible to express it with any accuracy or uniformity in £ s. d.; but it is nevertheless a *real* value, and when regarded as a comparative value, it may be said to be the *only* value which is capable of exact or scientific treatment. You may call it commercial value if you will; but as *cost* may also be said to be a commercial value, it is necessary to make the distinction already given. To save repetition, the term "value" will, wherever it occurs, be used in the sense just defined, viz., *comparative value to the shipowner*. It is not *absolute*, it is *comparative* value. The shipowner referred to is, of course, the *merchant* shipowner, and not the *war* vessel owner. Some of the arguments employed will not hold good for war vessels in time of actual hostilities, because circumstances are then likely to arise in which the value of the machinery of any ship to the nation may depend solely upon the amount of power exerted in a short time, irrespective of wear and tear, or coal consumption, or anything else. Some cases there are, even in commercial practice, in which wear and tear, consumption, and other adjuncts are of less importance than in others, but in no case are they of *no* importance at all. We therefore assume that the rule which is required is a rule which expresses in convenient mechanical units or terms the value *to the shipowner* of his propelling machinery.

Having reached this point, we can see what the rule must *not*

represent, and this is a point which cannot be too much emphasised. It must *not* represent the actual I.H.P. which will be, or is expected to be developed in every case. It *may* give the same result as the actual I.H.P. in many cases, but it is not necessary that it should do so, in fact it would not serve the purpose intended if it did do so in all cases. It is chiefly in this respect that the rule has been misunderstood. It has been assumed by many that the intention was to produce a formula which would give the actually developed horse-power in all cases, and because it failed to do so when applied to particular cases, it has by some been condemned as worthless. It has even been objected to on the ground that the ordinary means of arriving at the powers of engines by the indicator was on the whole more correct and preferable in every way.

In view of such deplorable misunderstandings as to the aim and meaning of any such rule as the one under discussion, we purpose to deal with this particular phase of the matter at some length.

The horse-power shown by the indicator is no criterion of the value of his machinery to the shipowner, unless he were possessed of some magic formula by means of which he could reduce this horse-power to the common denominator of a uniformity of all possible conditions under which engines and boilers are worked. Of such a formula he is not possessed, nor is he ever likely to be possessed of it. To compare the values of two engines by comparing their actual I.H.P. is—in the absence of identical working conditions—like comparing the values of the numerators of two fractions, without first reducing them to a common denominator.

Any given size of engines can be made to indicate vastly increased power by simply running them at a greater number of revolutions, or by increasing the period of admission of steam in the high pressure cylinder, or by both of these means combined; any given size of boiler may be worked very much beyond its normal power by forcing the fires. But this increase of power is obtained at the cost of increased wear and tear and increased fuel consumption, unless indeed it be possible to introduce some compensatory arrangements or devices in the case of the higher power engines and boilers. Apart, however, from the question of the possibility of introducing such arrangements, it is to be distinctly borne in mind that no elements beyond size of engines and boilers, and working pressures, can *possibly* be included as factors in any general rule. In the meantime in order to show distinctly what is meant when it is said that the actually developed horse-power is no criterion of value, take an example of two different engines indicating the same power.

As it is in the engines where the greatest variation of power is possible, the boilers are for the sake of simplicity omitted. The working pressure of both is also assumed equal, viz., 150 lbs.

$$\text{Say engines No. 1, } \frac{24 - 38 - 62}{36}.$$

$$\text{Engines No. 2, } \frac{21 - 33 - 54}{42}.$$

These two engines may be made without difficulty to indicate the same horse-power, and on this basis of value they would therefore be ranked as equal. Their proportions are in nowise abnormal, but are such as are to be met with in everyday practice. Assume the I.H.P. to be 1,230 in both cases, and to fix ideas, let the mean pressure reduced to the low pressure cylinder of No. 1 be 28 lbs., the revolutions per minute being 80. In ordinary circumstances it is very probable that the mean pressure and revolutions of No. 2 when indicating 1,230 horses will be about 31·6 lbs. and 80 revolutions. If this is so, then No. 2 must expand the steam less than No. 1, and so far as economy is affected by degree of expansion, the water consumption, and, therefore, the coal consumption of No. 2 will be higher than No. 1, to the extent of about $3\frac{1}{2}$ per cent. It is next to be noted that both engines are running at the same revolutions per minute, and therefore the longer stroke engines must—other things being equal—undergo more wear and tear. In respect, therefore, of both coal economy and wear and tear, No. 2 engines are inferior to No. 1. If No. 2 is made to equal No. 1 in coal economy, then No. 2 must run at the still higher speed of 90 revolutions per minute, thus very greatly increasing the piston speed and whatever evils or disadvantages this brings in its train. If, on the other hand, the revolutions of No. 2 be reduced to 72, which would bring both engines to approximately equal conditions as regards reciprocation and its effects, the coal consumption of No. 2 would rise to about 7 per cent. above No. 1. At this last speed the mean pressure of No. 2 will be about 35·1 lbs.

These figures are given in tabular form below:—

		M.P.	Revs.	I.H.P.
(1.)	$\frac{24 - 38 - 62}{36}$	× 28	× 80	× 1,230.
(2.)	$\frac{21 - 33 - 54}{42}$	× 31·6	× 80	× 1,230;
or,	do.	× 28	× 90	× 1,230;
or,	do.	× 35·1	× 72	× 1,230.

It is hoped that enough has been said to show once for all the absurdity of any proposal to take the actually developed horse-power as the basis of *value*, without specifying the conditions under which the power is obtained. Assuming the value of No. 1 engines at 1,230, the value of No. 2 engines *on the same basis* will be about 980; and these figures may represent *horses' power* or they may be simply *proportional or comparative numbers;* but, on the whole, it seems convenient to express the kind of value with which we are dealing in *terms of horses' power*, and to let its *amount* approximate to the average power developed by average engines in average conditions. The rule will therefore nominally represent comparative *I.H.P.*, but it will really and virtually represent comparative *value*—it will secure by its form that each horse-power for all sizes of engines and boilers, and pressures of steam, is obtained under certain limiting conditions as to piston speed and coal consumption, which conditions are imposed solely by considerations of comparative value.

On what then does *value* depend?

The *value* of the propelling machinery of a steamship depends—other things equal—upon the following factors, viz.:—

1.—*The cargo carried (or dead-weight) and the speed at which it is carried.* As the efficiency of the hull does not enter into the question, it is permissible for our purpose to write *displacement* instead of dead-weight. This factor then involves—

(*a*) I.H.P.

(*b*) General efficiency of mechanism and propeller.

2.—*The attendance and adjustment it requires, and the oil, stores, etc., which it consumes in order to keep it working at given efficiency.* This factor involves—

(*a*) Revolutions and speed of piston.

(*b*) Size and general efficiency of the bearing surfaces, design, proportions, and arrangement, accessibility of parts, workmanship, material, etc.

3.—*Its durability, or the period of time for which it will work at given efficiency with a given amount of attention, repair, and upkeep—in other words its wear and tear.* This factor involves—

(*a*) Revolutions and speed of piston.

(*b*) Size and general efficiency of the bearing surfaces, design, proportions and arrangement, accessibilty of parts, workmanship, material, etc.

(*c*) Duty from the boilers, *i.e.*, the degree to which the boilers are forced or otherwise, within certain limits.

4.—*The coal consumption.*—This factor involves, to a certain extent and indirectly, all the three preceding factors. For our purpose, however, it chiefly and directly involves—

(*a*) The boiler pressure, and the extent to which the expansion of the steam is carried in the engines.

(*b*) The ratio of the boiler heating surface to the horse-power.

(*c*) Efficiency of the boilers, of the steam in the engines, and the quality of the coal.

5.—*The weight of the machinery, including water in boilers, condensers, and pipes.* This factor involves all the others, inasmuch as it is mainly determined by the *dimensions* of the engines and boilers, and by the boiler pressure. It involves in addition—

(*a*) Type of engines.

(*b*) Type of boilers.

(*c*) Arrangement of machinery in vessel.

(*d*) Comparative scantlings adopted and factors of safety used throughout the machinery.

A careful examination of these factors will show that the first may, in a sense, be said to embrace all the others. It is the one which involves I.H.P., and I.H.P. may be affected by any one or every one of the other factors. As a criterion or measure of value (always taking value in the sense we are now using it) I.H.P. would therefore appear to be peculiarly appropriate. Value expressed in *terms of indicated* horse-power would appear to convey more *meaning* with it than value expressed in terms of any other horse-power, such as the old nominal horse-power, which horse-power indeed has *no* definite value, but has *any* value you like. *Indicated* horse-power is, moreover, a scientific unit, definite and familiar to all. Value in terms of *indicated* horse-power has more direct reference to the object for which power is applied than any merely proportional and comparative numbers could possibly have. Such considerations would seem to point to *indicated* horse-power as being the best unit available for the expression of comparative values.

Engines and boilers are built to perform *work,* and the *amount* of work performed may, for the present purpose, be taken as represented by *indicated* horse-power. *Other things being equal,* the *value* of machinery will, therefore, be proportional to the work performed, *i.e.,* to the I.H.P. But in order that the value may be proportional to the work performed the "other things" *must* be equal. These "other things" are comprised in the five value-factors enumerated above; and

if a rule could be framed which would embody all these factors, and embody them in such a way as to give each its due and proper influence in determining the result, it would be a *perfect* measure of value in every case, however varied the factors or conditions might be. But this is clearly impossible, both from a mathematical and a mechanical point of view.

In order to reduce the problem to dimensions which will enable it to be dealt with at all, it is necessary to make certain assumptions. From the statement of the various factors or conditions which determine value, it is evident that if value is to be expressed in terms of one of these factors, viz., I.H.P., all the other factors must be subordinated to it in some suitable and convenient fashion, and that as many of them ought to be included as is necessary for the purpose in view, and as is consistent with the simplicity which is desirable in any rule intended for general practical use. The factor I.H.P. in the statement given above therefore becomes the one which varies directly with, and measures value, and of the other factors some must be assumed constant or uniform in all circumstances, while others will be assumed to vary with circumstances in a way to be explained in due course. If in any number of engines all the factors of value, except I.H.P., are the same, *i.e.*, if they all work with the same efficiency of mechanism and propeller, with the same relative amount of attendance, adjustment, oil, and stores, with the same degree of wear and tear, with the same coal consumption per I.H.P., and if they are of the same weight per I.H.P., then it follows that the values of these engines will be exactly in proportion to their several I.H.P., and this is so for three reasons. 1st, because the same proportional amount of each horse-power is usefully employed in propelling the ship. 2nd, because each horse-power is obtained at the same expenditure of attention, upkeep, material, and fuel. 3rd, because the machinery of these various engines will continue to work at given efficiency for the same duration of time. But in practice it never—or at least very seldom—happens that all these factors are the same, and hence the I.H.P. of different engines developed in practice will never—or at least very seldom, except by merest coincidence—represent their proportional values. These factors must first be brought down to a uniform standard common to all engines, and then the horse-powers which *it is agreed would be developed* under these uniform conditions *will truly* represent the proportional values of the different engines.

Now it will be seen that many of the elements and conditions involved in the five factors enumerated, affect directly and largely the *amount* of

the I.H.P. The speed of piston, for instance, which is involved in factors 2 and 3 affects directly the amount of I.H.P. of the engines—a higher piston speed will give a higher I.H.P. from the same engines. The coal consumption also may affect directly the amount of the I.H.P. of both engines and boilers, inasmuch as the same engines are capable of giving increased power by less expansion of the steam due to a later high pressure cut off, and the same boilers are capable of yielding an increase of power by having the fires forced. If, therefore, the elements of those factors whose variation thus affects the *amount* of the I.H.P. can be embodied in a rule or formula in such a way as to secure mathematically that their influence on the amount of the I.H.P. will be *uniform* or proportional to value for all sizes of engines, for all amounts of heating surface, for all reasonable combinations of these two, and for all reasonable pressures of steam; and if, in addition, the influence of those factors whose variation does not directly or largely affect the *amount* or quantitative value of I.H.P. can be eliminated by the reduction of each of them to some generally recognised average or normal amount, uniform for all cases of one type, then in all cases of that type the I.H.P., *which would be developed* in practice under those uniform normal conditions, will be the I.H.P. given by the application of the above suggested rule *to* these cases; and will, moreover, be of such amount as will be exactly proportional to the value of all machinery of that type.

This is precisely what the N.I.H.P. rule does. It gives the amount of horse-power which will be developed *in all cases* in which those factors, conditions, or influences which affect the value of the machinery, and which are enumerated on page 179, are of uniform or *normal* amount. The uniformity or normality of those factors which depend upon the dimensions of the cylinders, the stroke of pistons, the heating surface of the boilers, and the working pressure, is secured (in a manner to be presently explained) by the *form* of the rule itself. The uniformity of factors or conditions, *other* than those depending upon dimensions and pressure, cannot possibly be secured by *any* rule, formula, or method, be it ever so complicated. They must be *assumed* to be uniform, just as the material and manufacture of beams are assumed to be uniform when the rule is applied which says that their strength is proportional directly to breadth and depth squared, and inversely to length; the rule can take no cognisance of the quality of the manufacture or of flaws in the material of the beam.

The foregoing analysis is exhibited in Table A, page 195. This table is not to be understood as being in *mathematical* proportion; it is simply a

summary in the form of a fraction of what has been already said on the relation between value and I.H.P.; the numerators containing the factors which affect value in a positive sense, while the denominators contain those which affect value in a negative sense. It shows how the factors which go to determine value lead up to N.I.H.P. Each statement is deduced from the preceding statement by a process of splitting up into groups of factors of the same denomination, so to speak; and this is done with the view of showing what groups of factors are included in N.I.H.P., and what are not included, but are left outside to rank as a variable and indeterminate coefficient.

We have now reached the N.I.H.P. rule by a process of analysis, which has been extended to such length with the view of distinctly showing—

1. The need that exists for having *some* measure of value.
2. The kind of value for which a measure is needed.
3. The factors which go to determine value.
4. The relation that exists between I.H.P. and value.
5. The relation that exists between N.I.H.P. and value.

Assuming that there is a need for having some measure of value, the conclusions that have so far been drawn are these:—

1. That the kind of value for which a measure is required is value to the shipowner.
2. That this value is most conveniently and aptly expressed in terms of horses' power which would be indicated under certain uniform conditions.
3. That value depends on many factors which no rule can embody, and that the only factors which it is possible or necessary to take into account are the dimensional elements of the engines and boilers, and the working pressure.
4. That a rule which embodies these latter factors properly will give a result proportional to value in all cases of given type.
5. That the N.I.H.P. rule does this, and is therefore a measure of value.

We next pass in review the individual factors of the rule, endeavouring to show that each is involved in such a way as to secure this result.

The rule is $\frac{(D^2 \sqrt[3]{S} + 3H) \sqrt[3]{P}}{100} = \text{N.I.H.P.}$

There are here four factors, which will be taken in the order most convenient for explanation. It is presumed that our hearers are familiar with the report in which the rule was published. This report is appended, and may be referred to for explanation of symbols, statement of normal conditions, etc. (See Appendix A, page 196.)

(1) D^2. As the rule expresses value in terms of I.H.P., the diameter squared, or the area of the low pressure cylinder, must enter into it. As the water consumption, so far as affected by the degree of expansion in the cylinders, is assumed uniform for any given boiler pressure, it is not necessary to take account of any other cylinders than the last one.

For weight calculations, it is, in cases of extreme variation of cylinder ratio, more accurate to take account of all the cylinders, or at least of the first and last one—the high pressure and the low pressure. The resulting complication of formula is, however, for our purpose, inadmissible.

Other things being equal, we therefore take D^2 as being proportional to value.

(2) $\sqrt[3]{P}$. This factor represents mean pressure reduced to the low pressure cylinder, and for pressures ranging from 50 lbs. to 250 lbs. it so happens that it represents with remarkable fidelity the mean pressures, which will usually be obtained if the steam be expanded to the same terminal pressure, with the same degree of efficiency. For proof of this, see Table I., Appendix A, page 200. In actual practice it will seldom happen that the efficiency will agree exactly with that assumed in the above table. It will sometimes rise above it, and probably as often fall below it. All that it can possibly represent is *average* efficiency. Variation in efficiency of the steam cannot be taken into account as a factor in any general rule such as this one. Such variation is a most important factor in the value of steam engines, but it is undoubtedly outside the pale of exact estimation by any combination of known dimensions, areas, pressures, or proportions. It falls within the category of the variable coefficient at the end of Table A, page 195, and as such is to be valued by other means than pure mathematics.

One of the objections urged against the rule has been, that it fails to take account of this variation, and is therefore useless, as a, measure of value. With equal justice it may be urged against the well-known expression for the locomotive performance of steamships, that it fails to take account of the variation of the coefficient of friction due to the state of ships' bottoms, and that it is therefore useless as a means of estimating resistance; with equal justice it may be urged against the law which says that the strength of shafts is proportional to the cubes of their diameters, that it fails to take account of the exact qualities of the material of which shafts may be made, and that it is therefore useless as a measure of the strength of shafts. In short, with equal justice, objections of this class may be brought against every general rule used in the wide range of engineering practice. Rules which apply *generally* can only do

so because they do *not* apply individually with absolute exactness. Nobody can calculate the *exact* strength of a particular shaft till he has tested the material of which it is made; he can only apply a general rule to it, which contains a factor deduced from the *average* quality of similar material previously tested. This rule will only give an *average* or estimated result, which may or may not correspond with the *actual* strength, but it is not therefore discarded as useless. In similar fashion nobody can calculate the *exact* efficiency of any particular engine till he has tested a duplicate engine in exactly the same conditions; he can only apply his experience drawn from an average of previous examples, and his estimate may or may not correspond with the *actual* efficiency.

It will be observed that the effect of the factor $\sqrt[3]{P}$ on the result is the same as if the degree of expansion in the engines were arranged to give a constant water consumption for constant pressure; that is to say, each boiler pressure is credited with its own economy, due to it in virtue of its *pressure* alone. This appears to be the only fair and the only scientific way in which to deal with degree of boiler pressure. Many engines are working at a higher mean pressure, and many at a lower mean pressure than is fixed upon in Table I., page 200, of the report. This may be due to two causes: first, to the former engines expanding the steam less, and the latter engines more than the average taken in the table. If this is so, the former will, other things being equal, be working at a higher relative water consumption per I.H.P. than the latter, and the application of the $\sqrt[3]{P}$ in the rule will, in rating their capabilities, correct this inequality. Or second, it may be due to a higher efficiency of ports, passages, valve adjustments and other arrangements in the former engines than is assumed in the table, and to a lower efficiency in the latter engines, and if this is so no possible function of P, or of any other known element of the engines, will estimate beforehand the relative values of the two. Indeed, amongst engineers themselves, opinions differ as to the exact influence upon efficiency of various proportions and arrangements. For instance, the influence of jackets, the influence of the relative ratios of the cylinder areas in multiple cylinder engines, the influence of the relative degree of expansion carried out in each cylinder of multiple cylinder engines, the influence of receiver capacity, the influence of the Woolf type of engine *versus* the receiver type, and the influence of many other points of detail in design and working.

And if opinions differ on these matters, it is not possible to formulate their influence, so as to be generally acceptable, even were it mathema-

tically possible—which it is not. But as to the influence of degree of expansion there can be no difference of opinion, at least within the limits of extent to which it is usually carried in engines of admittedly good average design and proportions.

(3) $\sqrt[3]{S}$. This factor represents piston speed, and its introduction into the rule, simply means that the piston speeds of engines of different lengths of stroke are assumed to vary as the cube roots of their respective strokes. This is perhaps the most important factor in the rule, as it is certainly the one to which exception is most apt to be taken, and naturally so, because of all the factors which go to determine value, as expressed in terms of I.H.P., piston speed is the one which in any given case is susceptible of the greatest variation.

It is not our intention to exhibit any collection of historical methods of dealing with stroke in rules for horse-power, although the study of such is instructive as showing the very great diversity of views which have been held as to allowable piston speeds. The particular function of the stroke fixed upon in the rule to represent piston speed, was not chosen in any hap-hazard fashion, nor was it simply *adopted* from any previously existing rule. The majority of rules for nominal horse-power we believe do contain $\sqrt[3]{S}$, and rightly so in our opinion, but in the present case, $\sqrt[3]{S}$ was decided upon solely because of its inherent fitness.

Many proposals have been made by critics of the rule, as to this matter of piston speed.

One gentleman objects that piston speed should have nothing to do with length of stroke, but that it should vary with the square root of the boiler pressure. Quite a common objection is, that the piston speed of the rule is not the *actual* piston speed; and to remedy this, it is proposed by some to embody in the rule the *estimated* piston speed, and by others to wait till the trial trip, and use the *actual* piston speed developed.

Again, it has been said that the piston speeds given in Table II. of Appendix A, page 201, are lower than the average of the present day, and that, for instance, they represent the practice of the Tyne more closely than that of the Clyde.

Now we are quite sure that proposals such as these, and objections such as these, would never have been brought forward, had the true object and purport of the rule been understood.

When it is remembered that it is comparative value expressed in terms of horse-power which the rule represents, it is at once evident that *estimated* piston speed or *actual* piston speed, will not serve the purpose required. Value is independent of the caprice of the estimator of piston

speeds. It is also evident that the matter of the practice of a particular district as against the practice of other districts, can only influence the rule by affecting the amount of the constants. The comparative values of different lengths of stroke are independent of the practice of any district as regards piston speeds.

Let us enquire at once—On what *does* piston speed depend? The answer to this in one sense undoubtedly is, that piston speeds *in actual practice* depend upon no principle, and upon no rule, but simply and solely upon the idea, the whim, or the necessity of the designer. Piston speed may be any amount you wish it to be, within extremely wide limits, and this without any reference to the length of stroke at all. There is *no* general consensus of opinion or of practice as to piston speeds corresponding to different strokes. If however it is asked—On what *ought* piston speed to depend? We have a question which is susceptible of quite a different answer from the foregoing.

From the point of view of value to the shipowner, piston speed ought to depend upon tear and wear, and durability, or in other words, upon factors 2 and 3, page 179. This being so, it is evident that piston speed will depend upon the length of stroke, and that piston speed must *vary with some function of the stroke;* whether that function be the cube root, the square root, or any other root being matter for determination.

Absolute piston speed does not concern us so closely as *relative* piston speed. The former—as has been already said—affects only the divisor or at most the two constants in the rule; the latter is a matter of principle and touches the very core of the question.

The value of engines to the owner depends—other things being equal—upon factors 2 and 3, page 179. That is to say, the greater the attention and adjustment required, the more oil, stores, etc., consumed, and the greater the tear and wear, the less is the value of each horse-power developed by the engines. Now it will not be denied that these factors are largely if not chiefly affected by piston speed. The greater the piston speed beyond certain limits for any one stroke—other things equal—the greater the tear and wear, etc.

We affirm that when piston speeds vary as the cube root of the stroke, the resulting tear and wear, etc., will—other things equal—be approximately the same for all strokes.

In order to explain this proposition, it will be necessary for us to go at some length into the question as to what causes tear and wear, etc. When we use the expression "tear and wear, etc.," it is to be understood that we refer to all that is involved in factors 2 and 3 already referred to, with the exception of the boiler element in 3.

Upon reference to page 179, it will be noted that piston speed is not the only cause of tear and wear, etc. There is in addition the size and general efficiency of the bearing surfaces, design and arrangement, accessibility of parts, workmanship, and material; but of none of these latter can any general rule take account, and we confine ourselves to what a general rule *can* take account of, viz.:—revolutions or piston speed.

When engines are driven beyond a certain speed of revolution, they invariably develop a tendency to vibration, which vibration affects their whole structure, and a tendency to jar and knock at the ends of the stroke. These undesirable manifestations may be to a certain extent reduced by nicety of adjustments and by nicety of balancing. The tendency to jar and knock may possibly be altogether overcome by these means, but the upkeep and attention required to preserve this nicety will be proportionately heavy. The tendency to general vibration on the other hand cannot, in the case of marine engines as ordinarily designed, be entirely obviated when speeds exceed a certain limit, which limit depends upon the length of stroke, upon the size and weight of the reciprocating parts, and upon the strength and rigidity of both the substructure and superstructure of the engines as a whole.

The difficulties to be met with in counteracting these tendencies may be taken as being proportional to the pressure per square inch of piston area required to alternately accelerate and retard the reciprocating parts. This pressure depends upon the weight per square inch of piston area of the reciprocating parts, upon the length of the stroke, and upon the square of the revolutions. It also depends upon the ratio of length of connecting rod to length of stroke, but this ratio, being assumed uniform, will not affect the result. If the weight of the reciprocating parts per square inch of piston were constant for all strokes, it is obvious that the pressures required to deal with acceleration would be constant for all strokes, when, and only when, the revolutions were proportional inversely to the square root of the stroke; *i.e.*, when piston speed varied at the square root of the stroke. But it so happens that the weight of reciprocating parts per square inch of piston area is not constant, but varies approximately as the cube root of the stroke. The diagram on Plate XVIII., shows the amounts of these weights per square inch of low pressure piston for actual engines of various strokes and diameters of cylinders. The curve drawn through the average of the spots is a curve following the cube roots of the strokes. There is a slight tendency shown by the spots towards a rate of variation which is faster than the cube root of the stroke allows, but the cube root seems on the whole a fair average.

The effect of this variation of weight, shown by the diagram on Plate XVIII., is such that the pressures required to deal with acceleration and retardation are constant when, and only when, the piston speeds for all strokes are proportional to the cube root of the stroke. In Appendix B, page 203, will be found the mathematical deduction of this conclusion.

The cube root is the function of the stroke which is used in the rule to represent the variation of piston speed with length of stroke. The rule therefore rates all lengths of stroke equally, so far as tear and wear, etc., depends upon shocks and vibrations arising from excessive revolutions and piston speeds.

Another undoubted source of tear and wear, depending upon piston speed, is speed of *rubbing* of such parts as pistons, guides, and shafting. This increases as piston speed increases, but its effects upon machinery do not seem to be of such a destructive nature as the effects due to inertia of moving parts. Indeed, this source of wear and tear can only be reduced to uniformity by a constant piston speed for all lengths of stroke.

This matter of piston speed is of such great importance that it would require, for its proper elucidation, a paper devoted all to itself. In the time at our disposal we cannot do justice to it; but before leaving this part of the subject it may be useful to compare the cube root with the square root, as it seems to be generally recognised that the choice lies between these two as functions of the stroke for representing piston speed. To assist this comparison, the diagrams on Plates XIX., XX., and XXI. are given.

It is to be understood that these diagrams show only *comparative* effects at different lengths of stroke. There is no attempt made to estimate the absolute tear and wear, etc., due to frequency of reciprocation, and to speed of rubbing of the bearing surfaces, nor even to determine with accuracy the relative importance of these two sources of tear and wear. This would be going beyond the scope and needs of our present purpose.

The diagram on Plate XIX. is simply a graphic representation of how piston speeds vary—(1) with the square root of the stroke, and (2) with the cube root of the stroke, and how the corresponding revolutions vary. It will be observed that, on the assumption that piston speed varies with $\sqrt[3]{S}$, the piston speeds are lower with long strokes and higher with short strokes than is the case on the assumption of $\sqrt{S}$, and that, of course, the revolutions with $\sqrt[3]{S}$ are lower with long strokes (but not very much), and higher with short strokes, than in the case of $\sqrt{S}$. The diagram represents the piston speeds given in the report for $\sqrt[3]{S}$.

If piston speeds be assumed to vary as $\sqrt{S}$, Diagram 3, Plate XX. shows the relative tear and wear due to different lengths of stroke. The tendency to vibration and to shocks, etc., due to frequency of reciprocation, increases as the length of stroke increases, and its relative amounts at different strokes are proportional to the ordinates of the shaded figure which lies *below* the base line A B. The ordinates of the shaded figure *above* A B represent relative piston speeds, and it will be observed that these increase very rapidly with the stroke.

If piston speeds be assumed to vary as $\sqrt[5]{S}$, Diagram 4, Plate XXI., shows the relative tear and wear due to different strokes. In all these diagrams the piston speeds are assumed the same at 42 inches stroke, for the sake of comparison. In this diagram the tendency to vibration and shocks arising from frequency of reciprocation is uniform and equal at all lengths of stroke, and the only variation in degree of tear and wear is that which may be due to increase of speed of rubbing with the longer strokes. As before, ordinates below the line A B represent inertia effects (in this case equal), and above A B ordinates represent relative piston speeds.

A comparison of the ordinates representing the total depth of the shaded figures in Diagrams 3 and 4 will show that, while they are equal at 42 inches stroke, they vary to a much greater extent, both for shorter and longer strokes, in Diagram 3 than in Diagram 4. On the whole, the conclusion would seem to be warranted that Diagram 4, representing as it does a much more uniform condition of things than Diagram 3, is the embodiment of a law of variation of piston speeds with stroke, which is preferable to that embodied in Diagram 3—that is, $\sqrt[5]{S}$ is preferable to $\sqrt{S}$.

(4) H (heating surface). This factor does not call for any lengthened notice. Its presence in the rule, combined as it is, in a certain way with $\sqrt[3]{P}$, secures to the boiler element its proportionate influence on the result.

The only question of vital importance that can well arise, is as to whether heating surface is the function of the boiler which best represents value. It has been proposed to take grate surface instead, but within a given shell, the latter can be varied very much without carrying with it a proportional variation in the value of the boiler. The heating surface is not so susceptible of variation within a given shell. It is in particular not susceptible of much *increase* beyond the normal amount, because of the necessity for preserving a practicable steam room, and accessibility to the internal parts of the boiler. And if it is much *less* than the

usual amount in a given shell the horse-power must also be less, whatever be the grate surface, or the boiler capacity, otherwise the proviso of a constant coal consumption is violated. Instead of heating surface, it has also been proposed to take the boiler capacity, or a proportional to it, viz., diameter^2 × length. But boiler capacity might be largely composed of steam room, or water room, or both; and these, when over a certain limit, are of no value.

Taking all things into consideration, the heating surface seems to be by far the best function by which to express boiler value in the sense in which we are using the term, and the association with it of $\sqrt[2]{P}$ gives to each foot of heating surface, a higher or a lower value, as the boiler pressure is higher or lower, in exactly the same way as is the case with a higher or lower pressure in the engines.

(5) The divisor. As to the way in which the various factors which have just been passed in review are combined in the rule, the report in the Appendix speaks for itself with sufficient clearness.

With regard to the divisor of 100, it will be readily understood from the general drift of this paper that the particular amount which may be fixed upon as a divisor is really of very little consequence, so long as it is a convenient figure. The divisor cannot alter the principle or principles upon which the rule is based; it can only affect the absolute amount of the result, and it cannot affect the amount otherwise than proportionately in all cases. But the rule is a comparative rule, hence the magnitude of the divisor is powerless to disturb the comparative nature of the rule.

As matter of fact the value of 100 was chosen for two reasons. First and chiefly because it reduced the result to what was considered a fair average horse-power developed on trial trip in average or normal circumstances; and secondly, because it was a most convenient number for use in calculation, Let it, however, be distinctly understood that whether the rule gives a result which is considered too high, or whether it gives a result which is considered too low, this affects in nowise the value or usefulness of the rule—an alteration in the divisor will alter the result equally for all cases. The rule is nothing if it is not comparative, and it is solely and entirely upon its *comparative* nature, upon its power of *comparing* the value of different engines and boilers, that its claim to usefulness rests.

Weight.—On page 180, No. 5, weight is given as one of the factors which go to determine value to the shipowner, and in Table A, page 195, it occurs at the beginning, but is merged into the general expression as the factors are specialised. The reason for its disappearance is to be found in the following proposition :—

For given type, design, proportions, and arrangement of engines and boilers built of given materials and to given factors of safety, the total weight is practically proportional to N.I.H.P.

An analytical investigation of the relation between weight and N.I.H.P. will, we have reason to believe, substantially support this; but, owing to the exceeding complexity and difficulty of the problem when dealt with analytically, it is well not to accept as true any result so arrived at unless it be substantially corroborated by results derived from actual practice. So far as the practical data at our command go, the conclusion indicated by analytical considerations is very well supported.

Time will not permit of our dwelling upon this part of the subject at such length as its importance demands. We can only briefly refer to the diagram on Plate XXII., as a demonstration from practice of the above proposition.

In this diagram abscissæ represent N.I.H.P. and ordinates represent total weight, including water. All the engines represented were carefully weighed before leaving the works, and the weights are, to our knowledge, correct. The only modification which has been made upon the weights as actually put on board has been to allow to each the same spare parts. This, it will be conceded, is necessary in order to render the comparison just.

Engines and boilers of a very wide variety of type are plotted down, and lines are drawn through the average positions of *three* distinct types, viz. :—

1.—Merchant screw engines of the ordinary vertical type. These vary considerably in design and scantlings, some being of a relatively heavy and some of a relatively light construction. They embrace twin screws as well as single screws, and double as well as single-ended boilers, but all the boilers are of the ordinary cylindrical return-tube type.

2.—Twin screw cruiser engines, both vertical and horizontal, having cylindrical boilers of the return-tube type, as well as of the Navy type. The examples given vary greatly in scantlings and design, some having framing of cast steel and some of cast iron.

3.—Twin screw torpedo-gunboat vertical engines, having modified locomotive type of boilers.

Some of the examples given constitute distinct varieties, different from the three types mentioned, and this explains why they diverge from the diagonals drawn for each of the three types. Double expansion and triple expansion engines are represented, and pressures ranging from 90 lbs. to 160 lbs. A greater number of examples might be given, but those plotted exhaust the list, the weights of which we are able to guarantee as being correct.

The large Diagram No. 6, Plate XXIII. is intended to save the trouble of calculating N.I.H.P., and is given to show at least one method by which the four factors of the rule may be combined so as to give the N.I.H.P. by inspection.

II.—Cost to the Builder.

So far as weight is an index of cost, N.I.H.P. is a fair index of cost of any one type. But weight *by itself* is, of course, no reliable index of cost. At the best, it can only be used—if used at all—as a *basis* by means of which to deduce comparative costs for different sizes. These comparative costs must then be modified according to the particular circumstances of the case and of the time. The circumstances referred to comprehend amongst others such variables as amount of spare gear, rate of wages, and price of materials.

Used in this manner, N.I.H.P. may be made very serviceable to the estimator of costs, but the engines and boilers should be dealt with separately. Every estimator, we presume, has *some* rule by which he arrives first of all at a basis cost, which basis cost he then manipulates according to the circumstances of the case and of the time; and we know of no general rule which gives such a reliable basis cost as that given by N.I.H.P.

It is of course impossible to exhibit in the form of a diagram, the relation between actual cost and N.I.H.P., on account of the great variations in cost, caused by fluctuations in the labour and material markets, and on account of other influences, the variations due to which cannot be determined with accuracy. Of one thing, however, we are convinced, viz., that for machinery of the same type and design, built under similar circumstances, and not differing enormously in size, the costs will be found to be, for all practical purposes, proportional to N.I.H.P. For example, take the engines mentioned on page 178, and assume that both are provided with boilers of 3,500 square feet heating surface, but that No. 1 is adapted for a working pressure of 170 lbs. per square inch, while No. 2 is adapted for a pressure of 150 lbs. per square inch. The N.I.H.P.

of No. 1. will then be 1,284, and the N.I.H.P. of No, 2 will be 1,095. Then if the cost of No. 1 is, say £100, the cost of No. 2 will, on the same basis, amount to $\frac{100 \times 1,095}{1,284} = £85{\cdot}3$.

Lloyd's Rule.—Lloyd's new rule for nominal horse-power was issued by Lloyd's Committee some time after the publication by this Institution of the Council's Report embodying N.I.H.P.

Lloyd's rule can be deduced from the N.I.H.P. rule by entirely omitting the boiler pressure, by changing the cube root of S into the square root of S, and by dividing by 5. The process of deduction will be found in Appendix C, page 204. Lloyd's rule is no simpler than the N.I.H.P. rule; both involve the same number of operations in calculation, Lloyd's involving three factors and three constants, and N.I.H.P. involving four factors and two constants. The range of application of Lloyd's rule is vitally impaired by the omission of boiler pressure. In addition to this, we consider, for reasons already given, that it unduly handicaps short strokes, and favours long strokes, because of the adoption of the square root in dealing with the stroke. Whether regarded as an index of value to the shipowner, or of cost to the builder, it is, therefore, only applicable to engines of the same stroke, working at the same boiler pressure.

TABLE A.

Value to the Shipowner	$\propto$	$\dfrac{(\text{Speed} \times \text{D.W.}) \times \text{durability}}{\text{Coal consumption} \times \text{attendance and upkeep, etc.} \times \text{weight}}$	
Do.	$\propto$	$\dfrac{(\text{I.H.P.} \times \text{eff. of mechanism and propeller}) \times \text{durability}}{\text{Coal consumption} \times (\text{attendance and upkeep, etc.} \times \text{weight})}$	
Do.	$\propto$	$\dfrac{\text{I.H.P.} \times (\text{eff. of mechanism and propeller} \times \text{durability})}{\text{Coal consumption} \times (\text{attendance and upkeep, etc.} \times \text{weight})}$	
Do.	$\propto$	$\dfrac{\text{I.H.P.} \times \text{durability due to speed of rev. and to boiler duty}}{\text{Coal consumption due to expansion} \times \text{attendance and upkeep, etc., due to speed of rev. and to boiler duty}} \times \dfrac{\text{Eff. of mechanism and propeller} \times \text{durability not due to speed of rev. nor to boiler duty.}}{\text{Coal consumption not due to expansion} \times \text{attendance and upkeep, etc., not due to speed of rev. nor to boiler duty.}}$	
Do.	$\propto$	$\dfrac{\left(\text{D}^2 \times \text{mean pressure} \times \text{piston speed} \times \text{durability due to speed of rev.}\right) + \left(\text{durability due to boiler duty}\right)}{\left(\text{Coal consumption due to expansion} \times \text{attendance and upkeep, etc., due to speed of rev.}\right) + \left(\text{coal consumption due to expansion} \times \text{attendance and upkeep, etc., due to boiler duty}\right)}$	$\times$ ... Do. ... ... do.
Do.	$\propto$	$\text{D}^2 \times \dfrac{\text{Mean pressure}}{\text{Consumption due to expansion}} \times \dfrac{\text{Piston speed} \times \text{durability due to speed of rev.}}{\text{Attendance and upkeep, etc., due to speed of rev.}} + \dfrac{\text{Durability due to boiler duty}}{\text{Consumption due to expansion} \times \text{attendance and upkeep, etc., due to boiler duty}}$	$\times$ ... Do. ... ... do.
Do.	$\propto$	$\text{D}^2 \times \sqrt[3]{\text{P}} \times \ldots \sqrt[3]{\text{S}} \ldots + \ldots \text{H} \sqrt[3]{\text{P}} \ldots$	$\times$ ... Do. ... ... do.
Do.	$\propto$	$\ldots \ldots \ldots \ldots \dfrac{\text{D}^2 \sqrt[3]{\text{PS}} + 3\,\text{H} \sqrt[3]{\text{P}}}{\text{C}} \ldots \ldots \ldots \ldots$	$\times$ ... Do. ... ... do.
Do.	$\propto$	$\ldots \ldots \ldots \ldots \dfrac{(\text{D}^2 \sqrt[3]{\text{S}} + 3\,\text{H}) \sqrt[3]{\text{P}}}{100} \ldots \ldots \ldots \ldots$	$\times$ A variable coefficient depending upon causes not susceptible of exact measurement; but probably fairly uniform for the individual manufacturer and for any one type of machinery.
Do.	$\propto$	$\ldots \ldots \ldots \ldots \ldots \text{N.I.H.P.} \ldots \ldots \ldots \ldots \ldots$	$\times$ ... Do. ... ... do.

II.—Conditions assumed as Normal.

1.—*That the steam, whatever may be its boiler pressure between 50 lbs. and 250 lbs. per square inch, is expanded by the engines to the same terminal pressure.*

This condition is necessary for the purpose of arriving at the power of the engines by themselves, but it is modified in its application by the rule under certain circumstances when the boilers are taken along with the engines, as will be explained further on.

2.—*That the expansion is effected by the engines with the same degree of efficiency for all pressures between 50 lbs. and 250 lbs. per square inch.*

This condition secures that for the higher pressures, engines of triple, quadruple, or more expansions must be used, the number of expansions depending on the pressure.

As a result of Conditions 1 and 2 it follows that the mean pressure reduced to the low pressure cylinder (Pm) may be assumed as proportional to the cube root of the boiler pressure ($\sqrt[3]{P}$), and further that its actual loaded trial trip value may be taken without sensible error as $5{\cdot}6\sqrt[3]{P}$.

See Table I., page 200, for proof of this.

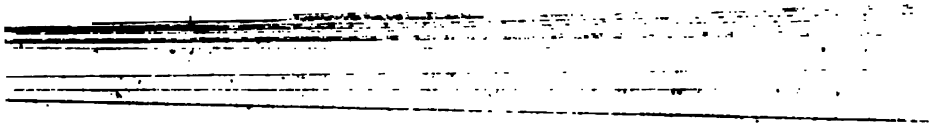
3.—*That the piston speeds of engines of different lengths of stroke are proportional to the cube roots of their respective strokes; and, further, that the actual loaded trial trip value of piston speed may be taken as* $144\sqrt[3]{S}$.

See Table II., page 201, for the variation of piston speed with length of stroke under this condition.

4.—*That in all cases where the engines and boilers bear to each other such proportions as to prevent Condition 1 from being fulfilled, without thereby violating Condition 3, the coal consumption per I.H.P. will not be affected, but will be constant for the same boiler pressure.*

When the engines and boilers bear a certain proportion to each other, which proportion is indicated in equation (C) further on, Condition 1, in conjunction with Condition 2, secures that the coal consumption will be constant for the same boiler pressure.

But when the engines and boilers vary, in their relative proportions, from what is here called the normal proportion, it is necessary that Condition 1 should be departed from, if the coal consumption is to be preserved constant for the same pressure, and if Condition 3 is not to be violated. Table IV., page 202, shows how nearly the rule fulfils this con-



I.H.P. of combined engines and boilers·

$$= \frac{\frac{D^2 \sqrt[3]{PS}}{52} + \frac{H \sqrt[3]{P}}{16}}{2}$$

$$= \frac{(D^2 \sqrt[3]{S} + 3{\cdot}25H) \sqrt[3]{P}}{104} \qquad \text{(By reduction.)}$$

This expression may without sensible error, and for convenience, be written :—

$$\text{N.I.H.P.} = \frac{(D^2 \sqrt[3]{S} + 3H) \sqrt[3]{P}}{100} \qquad \text{Q.E.D.}$$

NOTES.

1.—The only step in the above process of deduction which calls for further explanation is that by which the combined power of the engines and boilers is found by adding their separate powers and dividing by 2.

This step, though arbitrary, will be found to give results which very nearly conform to Condition 4, according to which condition the coal consumption per I.H.P. remains constant for any given pressure, even though the boilers vary from their usual proportion relatively to the engines.

Table IV., page 202, is, therefore, the justification for this step; and from this table it will be seen that the power given by the rule approximates very closely indeed *to the only power* which meets the proviso of a constant economy for a given working pressure, under varying relations of boilers to engines.

2.—For Paddle Engines the same rule may be used, with its coefficients modified to meet the altered condition of piston speed which usually obtains in these engines. Assuming, that under Condition 4, the piston speed of paddle engines may be taken at $90 \sqrt[3]{S}$, the rule may, without sensible error, be written—

$$\text{N.I.H.P. of Paddle Engines} = \frac{(D^2 \sqrt[3]{S} + 5H) \sqrt[3]{P}}{160}$$

and Equation (C) would become : $H = \frac{D^2 \sqrt[3]{S}}{5{\cdot}2}$.

3.—The Council considers the term "Nominal Horse-Power," as at present used, very indefinite and misleading as a measure of the power of marine machinery. If, however, instead of *Indicated* power, a quantity be required which will compare more nearly with what is known as "Nominal Horse-Power," the above rule may be used thus :—Nominal Horse-Power $= \frac{\text{N.I.H.P.}}{6}$

TABLE I.

SHOWING HOW THE MEAN PRESSURE (Pm) REDUCED TO THE L.P. CYLINDER VARIES WITH $\sqrt[3]{P}$, AND THAT THE NORMAL Pm MAY BE ASSUMED EQUAL TO $5{\cdot}6\sqrt[3]{P}$.

Boiler Press. = P.	Absolute Press. = P_1.	$\frac{P_1}{15}$ = R.	$\frac{1 + \text{H.Log.R}}{R}$ = C.	$P_1 C - 6$ = M.	M × ·663 (Pm as calculated.)	$\sqrt[3]{P}$.	$5{\cdot}6\sqrt[3]{P}$ (Pm assuming it to vary as $\sqrt[3]{P}$.)	Error per Cent.
50	65	4·33	·569	30·985	20·543	3·684	20·630	+ ·421
60	75	5·	·522	33·150	21·978	3·915	21·924	− ·246
70	85	5·66	·483	35·055	23·241	4·121	23·077	− ·710
80	95	6·33	·449	36·655	24·302	4·309	24·130	− ·712
90	105	7·	·420	38·100	25·260	4·481	25·093	− ·665
100	115	7·66	·396	39·540	26·215	4·641	25·989	− ·869
110	125	8·33	·374	40·750	27·017	4·791	26·829	− ·700
120	135	9·	·355	41·925	27·793	4·932	27·619	− ·630
130	145	9·66	·338	43·010	28·515	5·065	28·364	− ·532
140	155	10·33	·322	43·910	29·112	5·192	29·075	− ·127
150	165	11·	·308	44·820	29·715	5·313	29·752	+ ·124
160	175	11·66	·296	45·800	30·365	5·429	30·402	+ ·121
170	185	12·33	·285	46·725	30·978	5·539	31·018	+ ·129
180	195	13·	·274	47·430	31·446	5·646	31·617	+ ·542
190	205	13·66	·264	48·120	31·903	5·749	32·194	+ ·904
200	215	14·33	·255	48·825	32·370	5·848	32·748	+1·154
210	225	15·	·247	49·575	32·868	5·944	33·286	+1·255
220	235	15·66	·239	50·165	33·259	6·036	33·801	+1·603
230	245	16·33	·232	50·840	33·706	6·127	34·311	+1·763
240	255	17·	·225	51·375	34·061	6·214	34·798	+2·118
250	265	17·66	·219	52·035	34·499	6·299	35·274	+2·197

TABLE II.

SHOWING THE PISTON SPEED AND REVOLUTIONS ON THE ASSUMPTION THAT THE NORMAL PISTON SPEED IS EQUAL TO $144\sqrt[3]{S}$.

S. Stroke in Inches.	$\sqrt[3]{S}$.	$144\sqrt[3]{S}$. Piston Speed in Feet per Min.	Revolutions per Minute.
16	2·52	363	136·12
18	2·62	377	125·66
21	2·76	397	113·42
24	2·88	415	103·75
27	3·00	432	96·
30	3·10	446	89·2
33	3·20	461	83·81
36	3·30	475	79·26
39	3·39	488	75·07
42	3·47	500	71·42
45	3·557	512	68·2
48	3·63	523	65·37
51	3·70	533	62·70
54	3·77	544	60·4
57	3·84	554	58·2
60	3·91	563	56·3
63	3·98	573	54·57
66	4·04	582	52·9
69	4·10	590	51·3
72	4·16	599	49·9
75	4·21	607	48·56
78	4·27	615	47·3
81	4·33	623	46·1
84	4·38	631	45·

TABLE III.

SHOWING HOW THE AMOUNT OF HEATING SURFACE PER NORMAL INDICATED HORSE POWER VARIES WITH THE BOILER PRESSURE ON THE ASSUMPTION THAT THIS HORSE POWER EQUALS $\frac{H\sqrt[3]{P}}{16}$.

Boiler Pressure (P).	Square Feet of H.S. per Normal I.H.P. $\left(=\frac{16}{\sqrt[3]{P}}\right)$.
50	4·34
70	3·88
90	3·57
110	3·339
130	3·159
150	3·011
170	2·888
190	2·783
210	2·691
230	2·611
250	2·54

TABLE IV.

SHOWING THAT THE HEATING SURFACE MAY BE VARIED TO THE EXTENT OF 20 PER CENT. ABOVE OR BELOW THE NORMAL AMOUNT, AND THAT EVEN UNDER SUCH CIRCUMSTANCES THE RULE GIVES THE HORSE-POWER WHICH WILL BE OBTAINED IF THE COAL CONSUMPTION IS SENSIBLY CONSTANT FOR ANY GIVEN BOILER PRESSURE. $\left(\text{FOR ILLUSTRATION, ASSUME SCREW ENGINES } \frac{27''-43''-70''}{45''}\right)$.

D.	S.	P.	H.	$\frac{D^2\sqrt[3]{S}\,P}{52}$ Engines.	$\frac{H\sqrt[3]{P}}{16}$ Boilers.	$\frac{\text{Engines}+\text{Boilers}}{2}$	$\frac{(D^2\sqrt[3]{S}+3H)\sqrt[3]{P}}{100}$ (N.I.H.P.)	Normal Piston Speed.	Pm.	Engine Efficiency.	Boiler Efficiency.	Total Efficiency or Coal Consumption.
70	45	150	$\frac{D^2\sqrt[3]{S}}{3·25}$ = normal = 5363	1780	1780	1780	1780	512	29·81	100	100	100
70	45	150	20 % greater = 6435	1780	2135	1958	1950	512	32·66	96·7	105·9	101·3
70	45	150	20 % less = 4290	1780	1424	1602	1609	512	26·95	104·12	92·16	98·14

APPENDIX B.

Showing that the effects of the inertia of reciprocating parts are constant when piston speeds vary as the cube root of the stroke.

Let W = weight of the reciprocating parts in lbs. per square inch of piston area.

Let P speed = piston speed in unit time.

„ R = revolutions „ „

„ S = stroke in feet.

„ A = pressure in lbs. per square inch of piston area required to accelerate the reciprocating parts at the beginning and end of stroke.

Then $A \propto W\,S\,R^2$.

But $W \propto \sqrt[3]{S}$. See Diagram No. 1, Plate XVIII.

Therefore $A \propto \sqrt[3]{S}\;S\,R^2$.

„ „ $\sqrt[3]{S^4}\;R^2$.

or „ „ $S^{\frac{4}{3}}\,R^2$.

Then if A is to be constant for all lengths of stroke we have

$$R^2 \propto \frac{1}{S^{\frac{4}{3}}}.$$

$$R \propto \frac{1}{S^{\frac{4}{3}\times\frac{1}{2}}}.$$

$$„ \propto \frac{1}{S^{\frac{4}{6}}}.$$

$$„ \propto \frac{1}{S^{\frac{2}{3}}}.$$

But P speed $\propto R\,S$.

Therefore $\dfrac{\text{P speed}}{S} \propto R$.

„ $\dfrac{\text{P speed}}{S} \propto \dfrac{1}{S^{\frac{2}{3}}}$.

„ P speed $\propto \dfrac{S}{S^{\frac{2}{3}}}$.

„ „ $\propto \sqrt[3]{S}$.

That is to say, A is constant for all strokes, when piston speed varies as $\sqrt[3]{S}$.

APPENDIX C.

Showing how Lloyd's rule can be deduced from N.I.H.P.

$$\text{N.I.H.P.} = \frac{(D^2 \sqrt[3]{S} + 3{\cdot}25\ H)\sqrt[3]{P}}{104}. \quad \text{See Report.}$$

$$= \frac{(D^2 \sqrt[3]{S} + 3{\cdot}25\ H)\sqrt[3]{P}}{520}. \quad \text{Dividing by 5.}$$

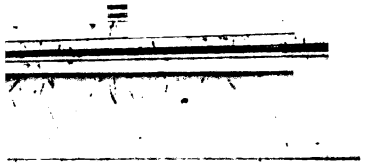
$$= \frac{D^2 \sqrt[3]{S} + 3{\cdot}25\ H}{97{\cdot}8}. \quad \text{Eliminating P and assuming it equal to 150.}$$

$$= \frac{D^2 \sqrt{S}}{97{\cdot}8} + \frac{H}{30{\cdot}1}.$$

$$= \frac{D^2 \sqrt{S}}{199{\cdot}1} + \frac{H}{30{\cdot}1}. \quad \text{Substituting } \sqrt{S} \text{ for } \sqrt[3]{S} \text{ and assuming } S = 72''.$$

$$= \tfrac{1}{2}\left(\frac{D^2 \sqrt{S}}{99{\cdot}55} + \frac{H}{15{\cdot}05}\right) \quad \text{Compare this with the following:}$$

$$\text{Lloyd's rule} = \tfrac{1}{2}\left(\frac{D^2 \sqrt{S}}{100} + \frac{H}{15}\right)$$



NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

SIXTH SESSION, 1889–90.

PROCEEDINGS.

SEVENTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON MONDAY EVENING, MARCH 24TH, 1890.

WM. BOYD, ESQ., PAST-PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the preceding General Meeting, held in Newcastle, on March 10th, which were approved by the members present, and signed by the Past-President.

Mr. R. L. WEIGHTON concluded his paper on the Institution's Rule for the "Normal Indicated Horse-Power of Marine Engines and Boilers."

The discussion which followed was adjourned.

Mr. G. BERGSTRÖM then read a paper "On the Structural Strength, etc., of Cargo Steamers of Different Types."

DISCUSSION ON MR. R. L. WEIGHTON'S PAPER ON THE "NORMAL INDICATED HORSE-POWER OF MARINE ENGINES AND BOILERS."

The PAST-PRESIDENT said, that before inviting discussion on this paper, which had been read by Mr. Weighton, he was going to ask them to excuse him for a moment on this occasion from the ordinary treatment of papers, for he occupied a somewhat peculiar position in regard to it. It would be within the knowledge of some of them that the subject of the paper was referred to by him in his second inaugural address to the Institution. A Committee called "The Engine and Boiler Power Committee" was the outcome of that address. The Committee, in the first instance, was under the guidance of the late Mr. William Clark, of Sunderland. He presided over one or two preliminary meetings; but, unfortunately, owing to his ill-health, a considerable length of time elapsed before much was done. On his untimely death, it was suggested that he (Mr. Boyd) should take his place as Chairman of this Committee, and the result was due mainly to the exertions of the scientific experts named on that Committee, notably his friends, Mr. Weighton, Mr. Alex. Taylor, and others. The matter went on for some time, and the rule appeared in their Transactions of two years ago, and was criticised more or less freely by various scientific papers both in their own and foreign countries. The Committee felt all along that the scope and form of the rule proposed by them and the lines they had set before themselves, were never fully appreciated or understood. Of course, the Committee having drawn out its report to the Council, its duties were at an end; but there were conversations at the Council meetings as to how the misunderstanding might be rectified, and the matter brought before the engineering public in a better way. Well, the end of it was that Mr. Weighton was asked to draw up this able statement, which he had prepared as representing the argument of the Committee as they wished to have it laid before the scientific community who were expected to use it. He wished also to say that this Committee was revived about three weeks ago, and a meeting was held to which Mr. Weighton's document was submitted,

and almost without an alteration was adopted by that Committee, so that in speaking that night on this paper, Mr. Weighton spoke as the mouthpiece of those whose duty it had been to draw up these rules. In saying that, he wished also to say that the ability with which this report had been concocted, and the comprehensive way in which various points that affected the rule had been laid before them, was Mr. Weighton's own, and the entire credit of the production was due to him. Having said this by way of explanation, he did not propose that night as Chairman to make a detailed speech upon the paper itself, but there was just one key-note he would like to strike. On page 181, Mr. Weighton began by saying—"In order to reduce the problem to dimensions which will enable it to be dealt with at all, it is necessary to make certain assumptions;" and on the last line of page 184, "Rules which apply *generally* can only do so because they do *not* apply individually with absolute exactness." He thought those two sentences explained the difficulties which many of their critics had found in the use of this rule. They had taken this rule and applied it to certain cases of their own individual manufacture, and because it had not fitted into them, condemned the rule as useless and worthless. Now, that was not the object for which this rule was formed at all. In the construction of the rules proposed, certain assumptions were made, certain assumed conditions taken. For example, one of them was the *loaded trial trip*. They might say that was not the very best conditions, it did not represent so and so; but that was one of the *assumed* conditions. It was not his place to recapitulate them now, but that was the foundation on which the rule was pitched, and once they attempted to get away from that foundation the fabric fell to pieces; but if that foundation was admitted as a sound one, then it appeared to them this rule was one that could be applicable in a variety of ways, and was "based upon sound scientific principles," which was, as he himself had originally defined it, the charter of their incorporation. He should like to say here, by the way, that in the paper it was stated that this rule might be of use to the estimator. Well, he wished to say that this rule was used in his office every day of his life, and in this way. They had certain standard patterns (like everybody else) of various sizes. A normal indicated horse-power was assigned to each of these standard patterns, based on the rule before them, and that was taken as their basis for estimating purposes, and with the normal indicated horse-power and normal heating surface attached to it. If that heating surface was departed from, spare gear and other things added, then the estimate was increased in accordance with the circumstances of the different cases. He

could bear testimony that in one office, at any rate, it was being used in ordinary practice with very great success for one of the very purposes for which this rule was established. The only other thing he had to say was on the question of Lloyd's rules. Some two years ago a rule was submitted by Lloyd's Registry in which one of the most important factors was the total width of grate surface. He did not think that rule ever got very far; but at the time it was brought forward he found that it operated in the following way in the case of two vessels for which his company had constructed the machinery. These vessels were exactly identical in every respect—fitted with the same size of engines, the same stroke and number of revolutions, same boiler, same working pressure, same heating surface. The boilers in one vessel contained eight Fox furnaces 3 feet 6 inches diameter, the other contained twelve plain furnaces 2 feet 11 inches diameter. Although both engines were identical except in the size and number of the furnaces, the horse-power given by the rule in the case of the plain furnaces was 347, and with the corrugated furnaces 304. He (Mr. Boyd) did not want to press a point of that kind unduly, as he thought that rule did not get very far, but he thought it showed that sometimes Lloyd's rules were open to criticism. This rule was abandoned; but then they came to Lloyd's *present* rule for nominal horse-power, and he confessed that he did think Lloyd's had again made a mistake in bringing forward the rule which *now* represented the views of that society. They had omitted what he (Mr. Boyd) and others thought a very important factor in the power of the engine, namely, *the pressure of steam in the boilers*, and it would almost seem that the rule had been made simply to get away a little bit from the rule already published (or at least, *proposed*) by our Institution. He did not know whether it was too much to hope that the result of this paper and the discussion upon it might be such as to induce Lloyd's to believe that this was, after all, the important element in the power of the machinery, and perhaps be willing to adopt their rule in its integrity. Whether that might be so or not was not for him to say. He must apologise for having kept them with this explanation of his position, but he was anxious to come and identify himself with Mr. Weighton's paper. He hoped it would be discussed from a scientific point of view, and he was quite sure Mr. Weighton would gladly welcome any criticism or discussion they might be good enough to give to the paper.

Mr. B. G. Nichol, who rose on the invitation of the Past-President, said that as a member of the Engine and Boiler-Power Committee, he was quite in agreement with the rule as framed, and consequently had really little or

nothing to say, except to congratulate Mr. Weighton on the masterly manner in which he had elucidated the reason for the existence and form of every factor in the rule. He thought Mr. Weighton's thorough and exhaustive paper would not only convince the members of this Institution of the utility and value of the rule as framed, but also those members of other institutions who had criticised the original report adversely, in most cases because they failed to grasp that the rule was not absolute as regards indicated horse-power, but comparative, and must be used in a comparative sense. Had Mr. Weighton's paper been presented along with the original report he believed those misunderstandings would have been avoided. He thought their gratitude was due to Mr. Weighton, both for his arduous work on the Committee, and for the vast amount of labour expended in the production of the paper and the preparation of the table and diagrams. He thought Mr. Weighton was very generous in presenting the Institution with the last of these diagrams (Plate XXIII.), which might in a great measure, and at least as far as the shipowner was concerned, be regarded as "engineering made easy."

Mr. JAMES PATTERSON said he was not in Mr. Nichol's position, that of a member of the Engine and Boiler-Power Committee, and was therefore free to criticise this rule adversely or otherwise as appeared to him best. The rule was now before them for criticism for the first time, although published for two years. During this time it had been criticised very freely elsewhere, especially by the venerable Institution in Scotland. He must say he thought most of the criticisms of the rule showed the criticisers had failed to understand it. He therefore agreed with Mr. Nichol that they owed a great deal to Mr. Weighton for the clear way in which he had explained it to them. The first point he noticed was that Mr. Weighton had very carefully explained what they understood to be the need of the rule, and he agreed with the Committee that there was a rule required as a standard to the shipowner for the value of the propelling machinery, and that was found in the Normal Indicated Horse-Power rule which they had given them. The first departure, from previous rules observable, was from *nominal* to *normal*, and this was not a mere changing of the word, but it was a displacement of a merely nominal or qualitative measurement, by an exact quantitative measurement which Mr. Dyer, in his paper to the Scotch Institution, told them was the tendency in every department of scientific investigation. This was a most important point, and should be emphasised, because the contrary had been assumed, viz., that normal indicated horse-power was merely a modified formula for nominal horse-power, and indeed the rule

had been called the *nominal* Indicated Horse-Power rule. Now, if the *nominal* indicated horse-power could be of use to anybody, he could find it by almost any process he chose, and could therefore give it any value he chose. One way familiar to many of them was to calculate what would be the highest mean pressure they hoped to obtain upon a trial trip, also from their inner consciousness determine the maximum revolutions to be attained at a trial trip, irrespective of all tear and wear, or whether the engines would run for more than four hours at that speed, and from these figures calculate the indicated horse-power. That would be a *nominal* indicated horse-power without doubt, but the figure so obtained would be of no use to anyone unless other conditions were known, such as coal consumption, wear and tear, etc., and then only if they had some standard to compare it by. Knowing these conditions they were at once able to appraise the value of that horse-power by comparing it, and the conditions under which it was hoped to attain it, with the horse-power which would be obtained under *normal* conditions, which horse-power our Council have called the Normal Indicated Horse-Power. Another rule for *nominal* indicated horse-power was, nominal indicated horse-power = (dia. of funnel)^2 × constant; but in this case the conditions which would have to be made known to make the rule of any value would be rather more numerous than in the first, including the sizes of the engines and heating surface of the boilers; but the two rules were of the same character. Now, granted that there was a need for a rule, was there not a great corresponding danger that any rule would tend to stereotype a certain class of engine and leave no room for the engineer obtaining credit for skill in his work? If this were a valid objection it would be a very fatal one to the rule. He did not think it could be valid if the rule was based upon correct principles. If any engineer could get more indicated horse-power out of his machinery than the normal indicated horse-power, without increasing his coal consumption, or wear and tear, and cost of maintenance, let him do so and claim credit for his skill. The rule in this case instead of refusing him credit actually pointed out what credit was due to him, and prevented the inferior engineer, whose machinery goes to pieces or consumes too much coal, claiming to be his equal, which he might in the absence of any exact basis of comparison; or if one engineer could get the normal indicated horse-power with less coal than another let him claim credit for it. This could be exemplified in the transition from compounds to triple expansion engines. If the coal consumption of a normal engine at 90 lbs. pressure were 2 lbs. per indicated horse-power per hour, then at 150

lbs. pressure it would be 1·69 lbs. per indicated horse-power per hour. Now, the consumption of the compound engine at 90 lbs. pressure is generally assessed at 2 lbs., but the triple at 150 lbs. is put at considerably lower than 1·69 lbs.; in this case there is a distinct credit due to the efficiency of the engine, and if any engineer can so improve the triple engine at 150 lbs. as to bring the coal consumption down to 1 lb. per normal indicated horse-power per hour, by all means let him do so and claim the credit for his skill. The different factors in the rule, the variables, were arranged in such a manner as to be true to all engines. The constant in the rule was chosen to represent the present practice at normal conditions. That these constants were only constant for the present time must be admitted, as also for certain types of machinery. This was shown in the rule itself, for the constant for the paddle engine was very different from the constant for the screw engine, and the difference cannot be explained by any difference of inertia effect, but simply by the difference in present practice in the two types. If at any future time the practice of engineers was so altered in the extent of bearings, etc., as to allow the use of higher speed of piston, he thought that might be embodied in the rule to give the normal indicated horse-power at that time; in the meantime use the normal of the present rule, and if they could get more power, get that more power and claim the credit for their skill. The next feature of value was the combination of boiler with the engine—a great advance upon any rules previously published. It was a most important point to shipowners, as it secured fair equality of steam producer to steam user, and in such a way that, as stated in the paper, the normal indicated horse-power could be varied 20 per cent. above and below the normal indicated horse-power without affecting the economy, which was a sufficient range for all present practice. He wished to refer to the cube root of the pressure being taken as the mean pressure of the cylinders. He noticed in the table that the mean pressure had been calculated for the terminal pressure of 15 lbs. absolute, and for the back pressure of 6 lbs. This seemed to him to be very high for the normal trial trip of a great many boats at any rate, he had therefore run out what the figures would be, taking 12 lbs. as the terminal pressure and 4 lbs. back pressure, and assuming the steam to expand in unjacketed cylinders. He found that they varied even more nearly as the cube root of the pressure than the figures given in the table. He thought that was a point to be put forward, as it showed that the mean pressure varied with the cube root of the boiler pressure, not in virtue of any particular assumed working conditions.

Mr. M. SANDISON wished to take the opportunity of complimenting the Committee on the very perfect formula they had evolved for determining the comparative value of marine machinery, and congratulated Mr. Weighton upon his very able exposition of the principles involved. The rule was certainly a more complete expression of value than that recently published by Lloyd's. Nevertheless, in certain cases—in the case of old vessels for example—some difficulty would be found in its application, because the rule embodied two factors, one of which, the boiler pressure, was variable, and the other, the heating surface, in the absence of detailed drawings, difficult to ascertain. The paper contrasted Lloyd's new rule unfavourably with the Normal Indicated Horse-Power rule. He did not think, however, that the latter was at all adapted to the purpose which Lloyd's Committee had in view when framing their rule, for the very obvious reason that the adoption of the Normal Indicated Horse-Power rule by Lloyd's would cause their fees to vary as $\sqrt[3]{P}$, that is to say, should the boiler pressure in any given vessel be reduced, by old age or otherwise, from 150 lbs. to 100 lbs.—a fall from 5 to 3·6—the fee for survey would be reduced some 15 per cent. Would Mr. Weighton tell them in his reply how the heating surface was calculated? How much of the furnaces and combustion chambers, and if the front tube plate was included?

Mr. J. F. WALLIKER said he should like to say a few words in answer to the remarks of the Past-President and other speakers with regard to the circulars issued by Lloyd's Register Committee on the nominal horse-power question. The first circular referred to was merely sent out to obtain the opinions of the engineering world as to its suitability, but for reasons unknown to him it was never embodied as part of the society's rules. With regard to the present formula, which had been so adversely criticised, he would like to say that it was issued as a nominal horse-power rule only, and if they looked at the circular on which it was published they would see that it was merely intended to mark a uniform scale of fees for *triple expansion engines* built under the survey of the society's officers. He did not think that the pressure or the length of the stroke made much difference in engines of this class, and this might easily be seen by comparing the results with $\sqrt[3]{P}$ eliminated. He was not behind the scenes when it was got out, but there it was, and he thought he had fully described the reasons for its use. Mr. Weighton's paper had been carefully thought out, and would certainly pave the way for the adoption of this rule, or a similar one, in the near future, and that the

publication of this paper would be a great help to that end. Although it had been alluded to, he thought, in thanking Mr. Weighton for his instructive paper, that the labours of those who had been associated with him in the drawing up of the rule should not be forgotten.

Mr. J. F. WALLIKER then moved, and

Mr. H. MACOLL seconded, that the discussion be adjourned till the next meeting.

This was agreed to.

ON THE STRUCTURAL STRENGTH, ETC., OF CARGO STEAMERS OF DIFFERENT TYPES.

By G. BERGSTRÔM.

[Read before the Institution on March 24th, 1890.]

In a previous paper read before this Institution the writer gave some results of calculations of longitudinal strains, but owing to the great amount of calculations requisite he was unable at the time to complete the paper as originally intended.

In the present paper he has, as a continuation of the first, attempted a comparison between the principal types of cargo steamers; and for the purpose of making the comparison more complete, and the paper on the whole more interesting, the stability, tonnage, etc., of each type has been computed, and the results recorded in a table of comparison. The main object in drawing this comparison is to illustrate, by means of diagrams and figures, in what respect one type is superior to another. To effect a fair comparison between different types of vessels three matters must be taken as constant, and in the present comparison the length, beam, and carrying capacity have been preferred. From the several sketches and tables it will be seen that the three types chosen are the well-deck, three-deck, and spar-deck, as representing the principal classes of modern cargo steamers.

It is not the writer's intention to advocate any of these types; but, seeing that in papers read before this and other Institutions on similar subjects different views have been expressed, he ventures to think that a comparison of this kind would not be out of place. Each type will first be treated separately, and then the comparison will be drawn.

Take first the well-deck steamer, which is precisely similar to the vessel treated in the previous paper, with a few alterations as to the scantlings due to increases of the same made by Lloyd's in a vessel of identical dimensions built last year. In the table of comparison on page 223 will be found her principal dimensions, Lloyd's numerals, displacement, etc., taken from

the actual vessel. The position of the centre of gravity of the light ship was determined from inclining experiments and curves of stability calculated. In Fig. 11, Plate XXXII., is shown the curve of stability when loaded homogeneously—including 'tween deck—to Lloyd's freeboard, and displays a fair amount and range of stability. In Figs. 5 and 6, Plates XXVI. and XXVII., are illustrated the various hogging and sagging strains when loaded homogeneously, and resting on waves of her own length. The height or depth of the waves is taken as 20 feet.

When on a wave crest, and with bunkers full, the vessel is under a hogging strain fore and aft, reaching its maximum near amidships, producing a tensile stress on the bridge deck gunwale of 4¼ tons per square inch. While the coals in the bunkers are gradually converted into smoke and ashes, and in their new form leave the vessel one way or the other, the hogging is steadily increasing. When the 340 tons of coal are burned out the hogging is about 25 per cent. greater.

Again, when on a wave hollow, the vessel is subject to sagging almost the whole length, except at the ends, where a slight hogging takes place. The strains when on a wave hollow are somewhat smaller than those when on a wave crest, and with bunkers full the maximum compressive stress on the bridge deck gunwale amounts to 4 tons, and with bunkers empty it is not more than 2¾ tons per square inch.

It is interesting to notice that as the coals are burnt the hogging is continually increased, while the sagging is decreased at a similar rate. The range between the maximum tensile and the maximum compressive stress, amounting to 8¼ tons on the bridge deck plating and 6¼ tons on the bottom plating, remains almost stationary, being only slightly less when the bunkers are empty.

Proceeding next to the three-deck steamer, it will be seen that she is of the same length, beam, and carrying capacity as the well-deck steamer, having a poop, bridge, and topgallant forecastle—the usual erections nowadays. The freeboard and depth moulded were worked out to suit the above conditions and the increased light weight. Having the principal dimensions established, and using the well-decker as a guide, the tonnage, stability, etc., were calculated.

On the amidships section, Fig. 2, Plate XXIV., it will be noticed that it was not necessary in any respect to increase the scantlings above those of the well-deck vessel, as the increase in the depth did not lead to any increase of the grades.

In the curve of stability, Fig. 11, Plate XXXII., of the three-deck steamer the erections have been omitted, as the ends, though closed with

bulkheads, are not perfectly water-tight. With ends not perfectly water-tight is understood, there being doors or openings in the bulkheads; but as these doors or openings are more in the centres of the bulkheads, there is no reason why the erections should not be recognised as adding to the stability—at least to some extent—and the dotted line B in the diagram, Fig. 11, Plate XXXII., shows the increase in stability due to the erections, up to an inclination of 42 degs., the water then entering the alleyways of the bridge.

The longitudinal strains in the case of the three-deck vessel are of exactly the same nature as those of the well-decker, but vary as to the extent. While the maximum hogging strains in the three-decker exceeds those of the well-decker by something like 18 per cent., the maximum sagging strains are somewhat less than in the well-decker. This tendency to greater hogging and less sagging in the three-deck type is a natural consequence of removing weights from amidships and placing them at the ends, and that this is the case will be readily perceived by comparing the different types as illustrated in Fig. 4, Plate XXV. The maximum range between the tensile and compressive strains in this case amount to $8\frac{3}{4}$ tons on the upper deck plating, and $7\frac{1}{2}$ tons on the bottom plating when the bunkers are full, falling slightly below this when the bunkers are empty. It will be noticed, when comparing the diagrams illustrated in Figs. 5 and 6, Plates XXVI. and XXVII., with those in Figs. 7 and 8, Plates XXVIII. and XXIX., that the respective maximum bending moments in the three-deck steamer take place as in the well-deck steamer near amidships but somewhat more forward.

It will now be necessary to refer briefly to the spar-deck steamer and then to pass on to the comparison. A similar procedure was followed in fixing her dimensions, as in the case of the three-deck steamer, and in the table will be found that the length, beam, and carrying capacity are the same as in the previous vessels. (See Plates XXX. and XXXI.)

As regards Lloyd's numerals the plating and equipment grades remained the same, while the frame grades became reduced below the others, affecting a slight reduction in some of the scantlings. The curve of stability was calculated, and referring to Fig. 11, Plate XXXII., it will be found that the maximum righting lever in the case of the spar-decker is considerably larger than in any of the other types, and is not attained before the vessel has heeled over to an angle of 46 degrees.

The relative strains on the spar-deck structure are very similar in nature and extent to those of the three-deck type, and while slightly larger in some cases they are rather less in others. It is not necessary

in this paper to refer to the permanent strains on the vessels, as they are not those which regulate the provision of strength, besides—as shown in the preceding paper—being very small.

It may be well before proceeding to here point out that when in the three-deck steamer, as also in the spar-deck, the absolute maximum stresses on the structure take place near amidships, where the bending moment is greatest, the heaviest straining of the well-deck structure is felt immediately abaft the bridge in way of the raised quarter deck, notwithstanding the bending moment at that point is much smaller than amidships. The respective strains at this point are about 15 per cent. larger than amidships, but from hence the straining decreases very rapidly towards the after end; in fact, only a few feet abaft the break the strains are again less than amidships. This would be a blow, it may be said, at the well-decker as regards its longitudinal strength, compared with the other types if this was not guarded against by means of doubling the sheer-strake and overlapping the stringers at this point, and thus considerably reduce the straining. Moreover, to some extent this no doubt weak point of the structure may be strengthened by avoiding any butting of the shell in the vicinity of the break.

It is now necessary to see how the different types stand when treated from a comparative point of view. As already stated, the length, beam, and carrying capacity are identical for each type, and the depths made to suit this condition. The sheer and coefficient of fineness are the same in each case. It will be seen from the table that while Lloyd's numerals as regards plating and equipment run pretty close, the frame number is smaller for the three-deck type than the well-deck, and in the spar-deck it is considerably less, bringing her frame grades below the other two vessels. This would seemingly infer that the spar-decker is of less strength than the other vessels, but that this is hardly so is partly illustrated by this comparison, and will be further demonstrated.

Taking the different items in the table of comparison *seriatim*, the next item is that of the tonnage of the three types, and it will be noticed that, while the three-deck vessel is of the least tonnage, the well-decker measures the largest. That the three-deck tonnage is smaller than that of the spar-deck is due to the after end of the bridge not being closed, and consequently only part of it measured in the gross tonnage. But, even in the event of closing the bridge at both ends, the three-deck tonnage would still be considerably below that of the well-deck, although slightly above the spar-deck tonnage. But as regards cubic

capacity, the well-decker shows to an advantage, and dividing the said capacity by 40, the table shows that the three-decker falls very much short of the well-decker, the spar-decker approaching her by about 109 tons. In the case of draught of water, the well-deck type has a slight advantage, from a commercial point of view, over her two rivals.

Next comes the question of freeboard of the three types, and the figures given in the table have been worked out as near as possible from the present freeboard tables. The writer is not prepared to argue the question of freeboard in the present paper, but will not pass over, without a few remarks, so important a factor, affecting as it does the stability, and, perhaps more directly, the straining on the vessels.

As will be observed in Figs. 2 and 3, Plate XXIV., the main deck is taken as being of wood, and had steel been substituted an allowance in the freeboard of 2½ to 3 inches would have been granted, and consequently the vessels could have been built that much shallower, still carrying the same cargo. This diminution in freeboard and depth would certainly have decreased the stability, and equally certain, increased the principal or longitudinal strains on the vessels.

Again, on comparing the surplus buoyancy possessed by the different types when loaded to the above freeboards, it will be seen that the well-decker heads the list with a considerable excess of spare buoyancy.

It will be necessary here to state that while in the well-decker all the erections above the main deck have been considered buoyant, the poop and forecastle only are included in the spare buoyancy percentage of the three-deck vessel, as the bridge has openings in the after end. That with this excess of spare buoyancy in the well-decker did not follow a corresponding excess in stability is manifest from the curves of stability in Fig. 11, Plate XXXII. From the figures in the table, page 223, giving the light and dead-weights carried we gather that we are dealing with the fuller kind of cargo steamers. As the well-decker was an actually built vessel it was not so very difficult to arrive at the probable light weights of the other types, and that these weights would be somewhat heavier in the three and spar-deck vessels is obvious. It might be said that the light weights of the three-decker and spar-decker are rather small. But knowing there is no increase in the scantlings—in fact, in the spar-decker they are less in some cases—above the well-decker, and the equipments and outfits generally are very much the same as in the well-decker, the writer thinks the light weights as given in the tables are not very far out. This is perhaps the most eminent feature in the well-deck type, as it can be built for less money, and, as already mentioned, with less draught of water than the other types.

As regards the density of homogeneous cargo, the writer is of the opinion that a better ship than the spar-deck type could hardly be designed, as her density, being the medium between the other two types, enables her to fill the holds with cargoes which would not immerse the three-decker to the same draught of water, while the well-decker in carrying the same cargo as the spar-decker would also carry a considerable amount of empty space. The disadvantage in either case is evident. Now, supposing the respective types were filled with suitable homogeneous cargoes to immerse them to their assigned load draughts, it would be interesting to see what stability and height of platform they display. In Fig. 11, Plate XXXII., is illustrated the curve of stability of each type when loaded homogeneously, and with bunkers full, and it will be seen that up to 18 degs. the three-decker has a larger righting moment than even the spar-decker. This is due to the greater metacentric height in the three-decker than in the other two vessels. But from this point the spar-decker commences to gain stability more rapidly than the three-decker, and before her maximum righting lever is reached the three-decker has passed its angle of greatest stability, and is fast approaching the vanishing point. The well-decker, on the other hand, has not been so fast in gaining stability as the spar-decker, though she follows her pretty closely in range; in fact, while her angle of maximum stability is slightly behind the spar-decker, she supersedes her in the final range. When the bunkers are empty the stability is slightly increased in each case. The writer will not dwell at any length upon the properties of stability, though a complete investigation of this matter in vessels of the same dimensions but different types would be highly instructive, and he believes would also furnish proofs of the three-decker not being so deficient in stability as is generally assumed.

There is no doubt that three-deck vessels are afloat with very little stability, and probably this want of righting power and range of stability have been the cause of the loss of some of this class of steamers. But it will not do to condemn the type on this point before knowing the reasons why, and this want of stability could easily be traced to deficiency of beam in those three-deckers. The present comparison is a sufficient proof that a three-deck steamer can be built with a fair amount of stability if of reasonable proportions to suit the design.

In again referring to Fig. 11, Plate XXXII, and the curve of the three-decked steamer, and supposing the bridge water-tight at both ends and the dotted curve B continued, it would cross the base line first at 67 degs., and thus prove the three-decker, with the aid of her water-tight

erections (quite as waterproof as the well-decker), a virtually stabler vessel than the well-deck. As to the height of platform which is considered of such vital importance, it cannot be denied the well-decker has plenty of it, and no doubt makes her a very dry bridge in ordinary weather on which to cross the Atlantic when compared with the other types, this is partly illustrated in Figs. 4 and 12, Plate XXV., But how is the well getting along in rough weather? Heel the three types over to an angle of 15 degs., when it will be noticed, in Fig. 13, Plate XXXII., the well is open to receive a few tons of water, while the decks in the other vessels are still considerably above the water surface. But that the water that will enter the well during heavy rolling and pitching would not to any noticeable extent tell on the stability or longitudinal strength of the vessel is obvious, seeing the well is only 24 feet long. As for the material forming the four sides of the well, it has to be sufficiently strong to withstand the pressure of the water that does not escape through the ports, but rushes in all directions as the ship oscillates. The most exposed part in the well is naturally the after end or bridge front, as the water shipped from over the bow or bulwarks would at once or finally, owing to the rise of sheer, rush aft, and therefore this part of the structure requires special attention from the designer.

Passing on to the origin of the paper or the structural strength of the vessels, the writer has striven to show from the detailed explanation of each type that the nature of the longitudinal bending moments when moving amongst waves is very much the same for each vessel, while the intensity of stress produced differs to some extent. The strains given in the table are those on the bridge, upper and spar-deck plating respectively, and bottom plating, representing the stresses in tons per square inch, corresponding to the maximum bending moments.

From what has been stated in the earlier part of the paper, and with the aid of the figures in the table, it must be admitted that the well-deck structure is not subject to quite so heavy straining when on the crest of a wave as the three or spar-deck structures.

Again, when in the hollow of two waves there is little or no difference as to the amount of stress upon the different structures. But as is well known a vessel would not be at rest under these conditions, and the actual bending moments would probably be very different, both in nature and extent, to the estimated.

But for the matter of comparison the figures in the table, page 223 will give an idea what the relative maximum strains would probably be if the vessels were for a moment in a state of equilibrium before moving from a crest to a hollow, and *vice versâ*. Before bringing this part of the

paper to a close, the writer wishes to draw the attention to the function of the depth in resisting longitudinal bending. If we refer to the table and compare the sectional areas and the moments of resistance of the three-deck and spar-deck vessels, it will be observed that although rather less material is used in constructing the spar-decker, she presents, by virtue of her depth, greater resistance against longitudinal bending than the three-deck vessel. That in the three-deck steamer the maximum hogging strains are smaller than in the case of the spar-deck steamer is due to the weight of the bridge in the former tending to lessen the bending when on the summit of a wave. But if this bridge is removed, or better, shortened to 20 feet—the length of the bridge in the spar-deck steamer—the hogging would exceed that of the spar-decker in spite of the necessary increase in depth and consequent increase in resistance.

From what has thus been remarked, and knowing that the ranges between the maximum tensional and the maximum compressional strains are very much the same in the spar-deck and three-deck vessels, we may conclude that the spar-deck vessel with her thinner top sides, when built in accordance with present rules for scantlings and freeboard, compares favourably as regards longitudinal strength with her sister ship the three-decker; in fact, is equally strong. Again, what is it that makes the well-deck structure with her light top side show to such an advantage in resisting longitudinal bending but the height of the girder as we may term the structure? But, while comparing the longitudinal strains we must not lose sight of the many other strains acting on a vessel in the transverse, shearing, and twisting directions, not to mention the increase of straining on the upper structure as the vessel passes through a series of inclinations. To calculate and explain these complicated strains requires a great deal of thought and labour, and the writer is obliged to leave them for the present.

The last items in the table are the trims of the vessels when loaded homogeneously. There is nothing remarkable about them except that, supposing the trims of the well-decker to be the actual trims, the spar-decker exhibits less tendency for trimming by the head than the other types, notably the well-decker.

Having thus endeavoured to give a brief explanation of the various diagrams and items engaged in preparing this comparison, the writer can only add that a graphical representation of the results will accompany the paper. (See Plate XXXIII.) In conclusion, he hopes, knowing the paper is far from complete, that some valuable information will be added during the discussion.

TABLE OF COMPARISON.

	Particulars.	Well-deck.	Three-deck.	Spar-deck.
	DIMENSIONS—	′ ″	′ ″	′ ″
1	Length between perpendiculars	290 0	290 0	290 0
2	Beam extreme	38 0	38 0	38 0
3	Depth moulded to main deck	22 3½	18 0	20 0
4	,, upper ,, ...	29 0½	24 9	27 0
	ERECTIONS—	′ ″	′ ″	′ ″
	Poop	28 10	28 10	None.
	Quarter deck	88 0	None.	None.
	Bridge	118 0	54 0	20 0
	Forecastle	31 2	31 2	None.
	LLOYD'S NUMERALS—			
5	Frame number	79′ 2″	77′ 1″	74′ 7″
6	Plating ,, ...	22,822	22,224	21,500
7	Equipment number	25,437	25,424	25,540
8	Beams in length	7·62	7·62	7·62
9	Depth in length	12·51	11·3	13·84
	TONNAGE—			
10	Gross Register	2,296	2,130	2,144
11	Net ,, ...	1,494	1,381	1,390
12	At 40 cubic feet	3,969	3,629	3,860
	DISPLACEMENT, CARRYING CAPACITY, ETC.—			
13	Load draught above keel	20′ 4″	20′ 8″	20′ 7½″
14	Displacement	4,955	5,045	5,035
15	Freeboard (top of iron deck)	2′ 0″	4′ 1½″	6′ 5″
16	Spare buoyancy	34·11 %	27·64 %	30·83 %
17	Light weight	1,375	1,465	1,455
18	Cargo and bunkers	3,580	3,580	3,580
19	Density of homg. cargo filling all available space	49 cub. ft.	44·81 c. ft.	47·65 c. ft.
	STABILITY LOADED HOMG. AND BUNKERS FULL—			
20	Maximum stability at	45°	34¼°	46°
21	,, righting lever	8¼ ins.	7½ ins.	12¼ ins.
22	Vanishing stability at	71½°	56¾°	71°
23	Metacentric height	5 ins.	13¼ ins.	10 ins.

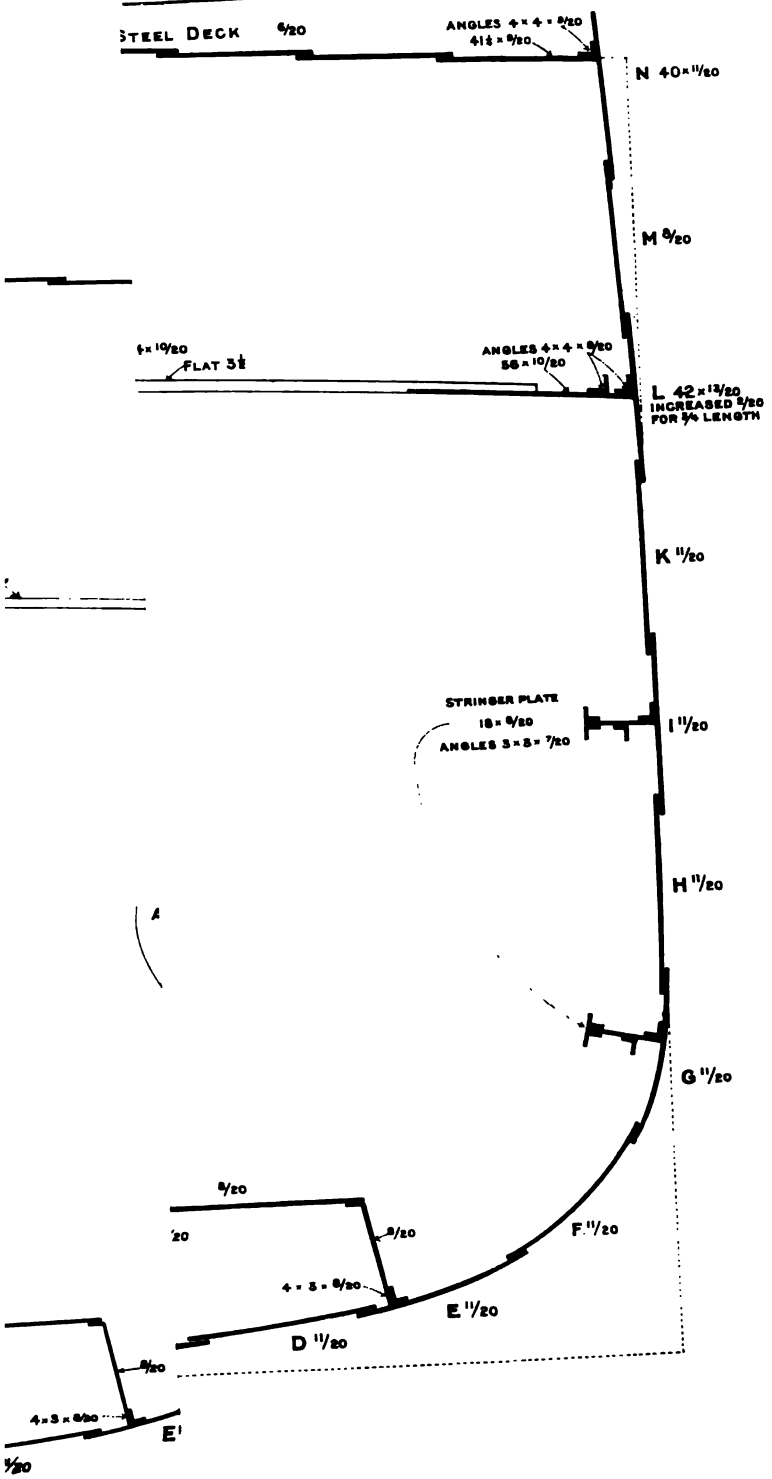
TABLE OF COMPARISON.—CONTINUED.

	Particulars.	Well-deck.	Three-deck.	Spar-deck.
	STRAINS—			
	On a Wave Crest, with Bunkers full—			
	Nature of strain...	Hogging.	Hogging.	Hogging.
24	Maximum bending moment	38.210	40,800	44,030
25	„ tensile strain	4·22	5·03	5·31
26	„ compress strain	3·18	4·27	4·32
27	$\frac{D \times L}{M}$	37·6	35·85	33·16
	On a Wave Crest, with Bunkers empty—			
	Nature of strain...	Hogging.	Hogging.	Hogging.
28	Maximum bending moment	48,120	48.600	51,200
29	„ tensile strain	5·31	6·0	6·18
30	„ compress strain	4·0	5·1	5·02
31	$\frac{D \times L}{M}$	27·81	28·07	26·6
	On a Wave Hollow, with Bunkers full—			
	Nature of strain	Sagging.	Sagging.	Sagging.
32	Maximum bending moment	36,160	30,210	28,670
33	„ tensile strain	3·0	3·17	2·81
34	„ compress strain	4·0	3·72	3·46
35	$\frac{D \times L}{M}$	39·73	48·44	50·93
	On a Wave Hollow, with Bunkers empty—			
	Nature of strain...	Sagging.	Sagging.	Sagging.
36	Maximum bending moment	24.000	18.950	20,010
37	„ tensile strain	2·0	2·0	2·0
38	„ compress strain	2·65	2·34	2·41
39	$\frac{D \times L}{M}$	55·75	72	68
40	SECTIONAL AREA AMIDSHIPS	1,300 sq. in.	1,266 sq. in.	1,262 sq. in.
41	NEUTRAL AXIS BELOW HALF DEPTH ...	2′ 0¼″	1′ 0½″	1′ 4¾″
	MOMENT OF RESISTANCE—			
42	At gunwale plating	9,048	8,106	8,280
43	At bottom plating	12,030	9,520	10,193
	TRIM—			
44	Loaded homogeneously with bunkers full	7½″ fore.	1¾″ fore.	On an even keel.
45	„ „ „ empty	10½″ „	4″ „	2½″ fore.

ngth of

FIG. 3.

AR DECK



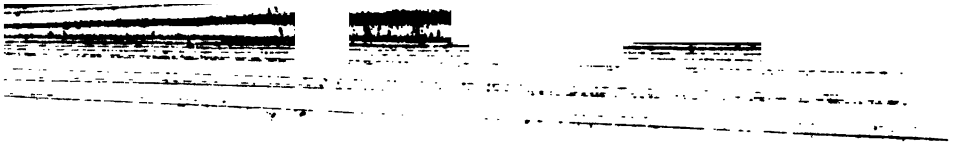
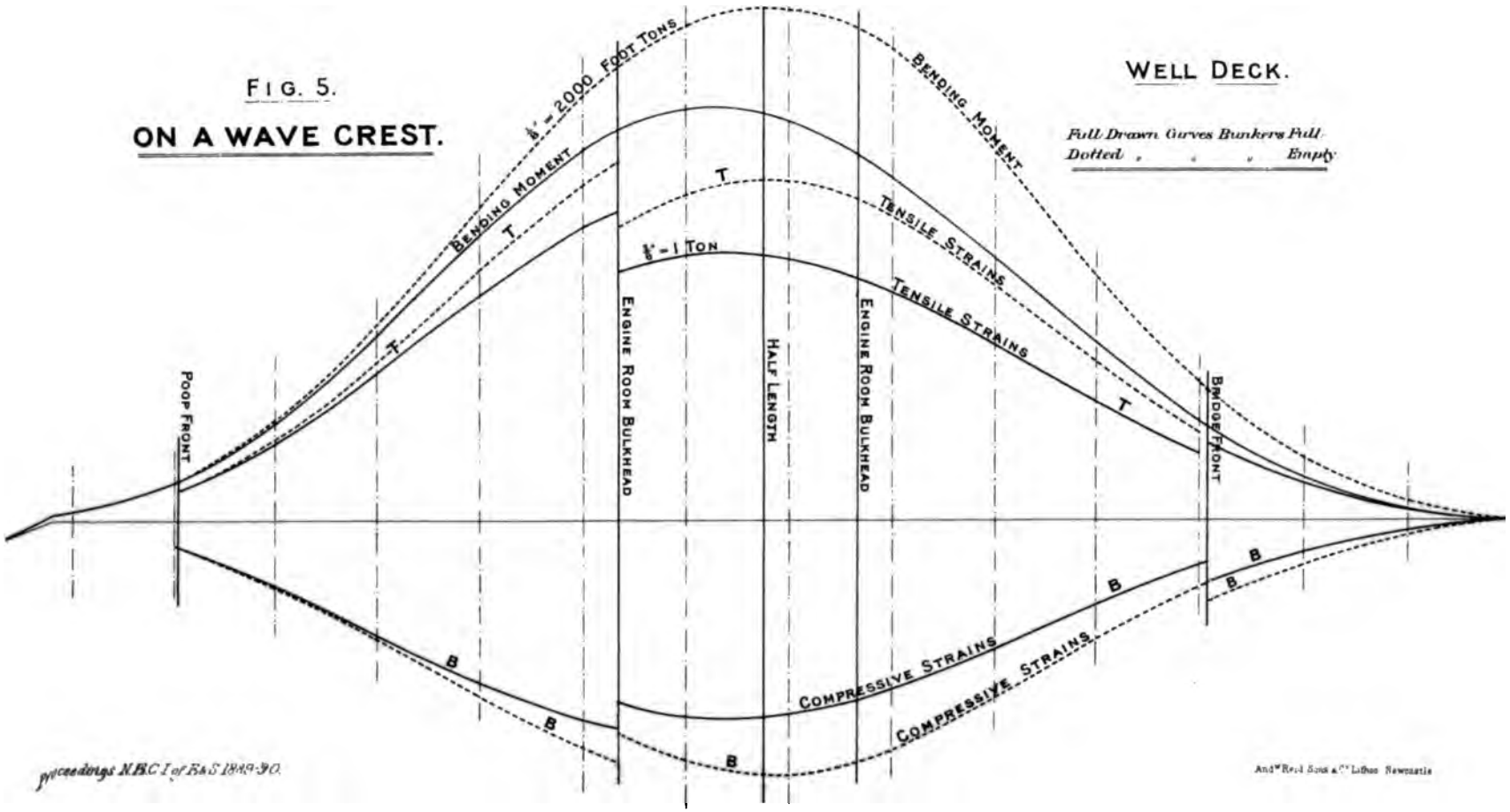


FIG. 5.

ON A WAVE CREST.

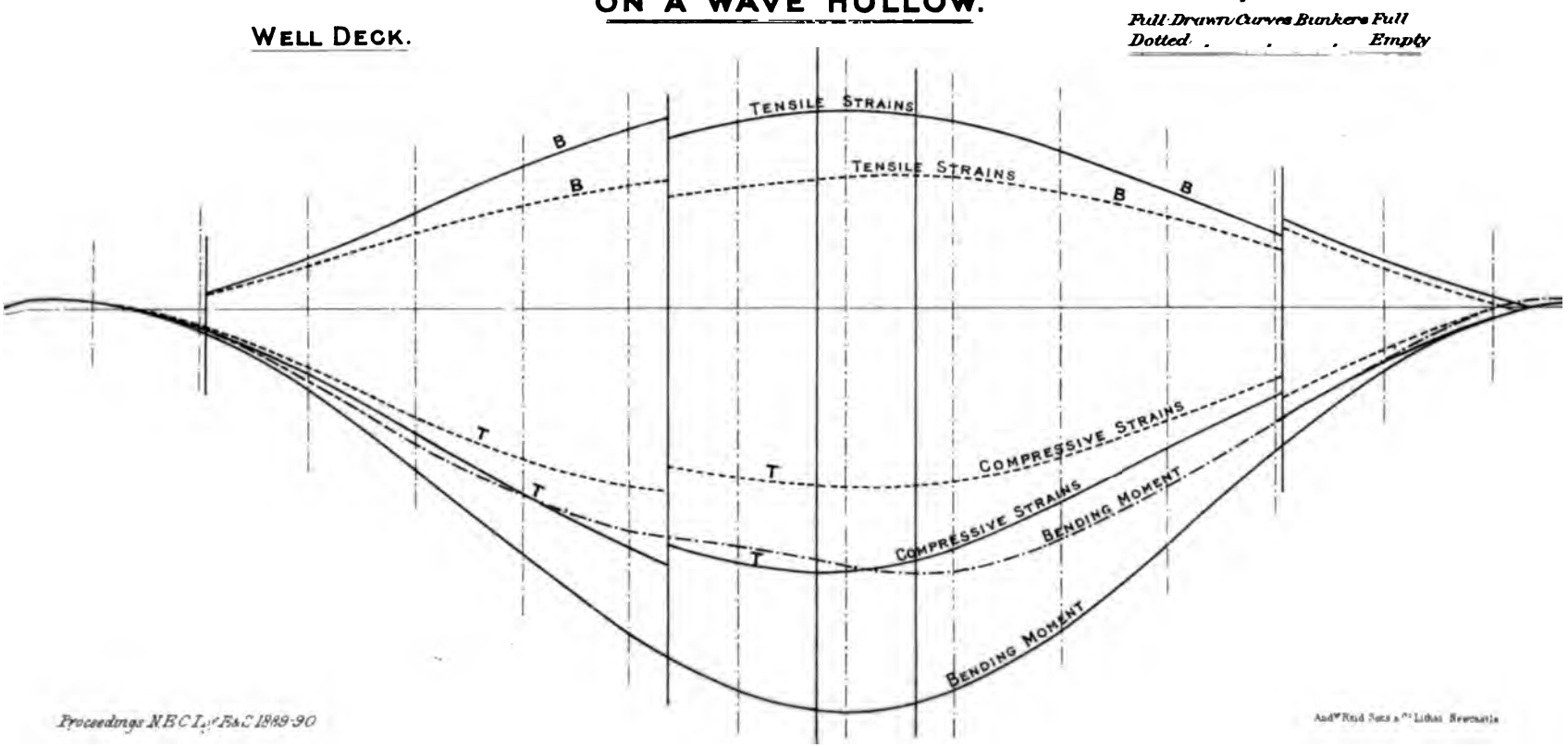


And.w Reid Sons & Co. Lithos Newcastle

To illustrate Mr. G. Bergstrom's paper "on the Structural Strength of Cargo Steamers of Different Types."

FIG. 6.

ON A WAVE HOLLOW.



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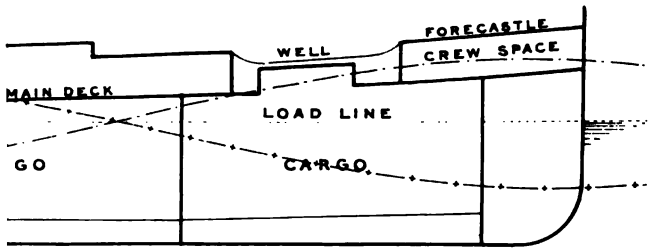
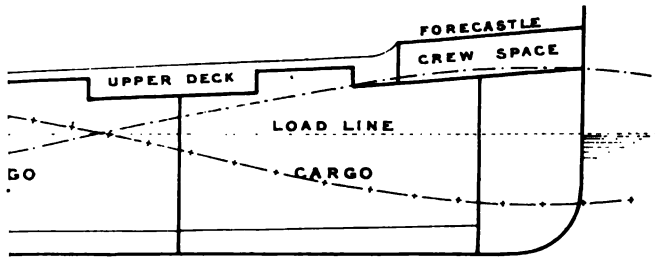
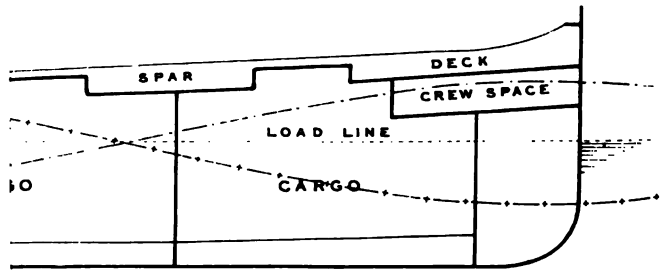
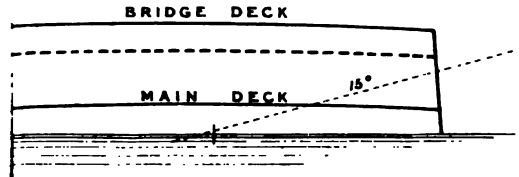






PS.

WELL DECK



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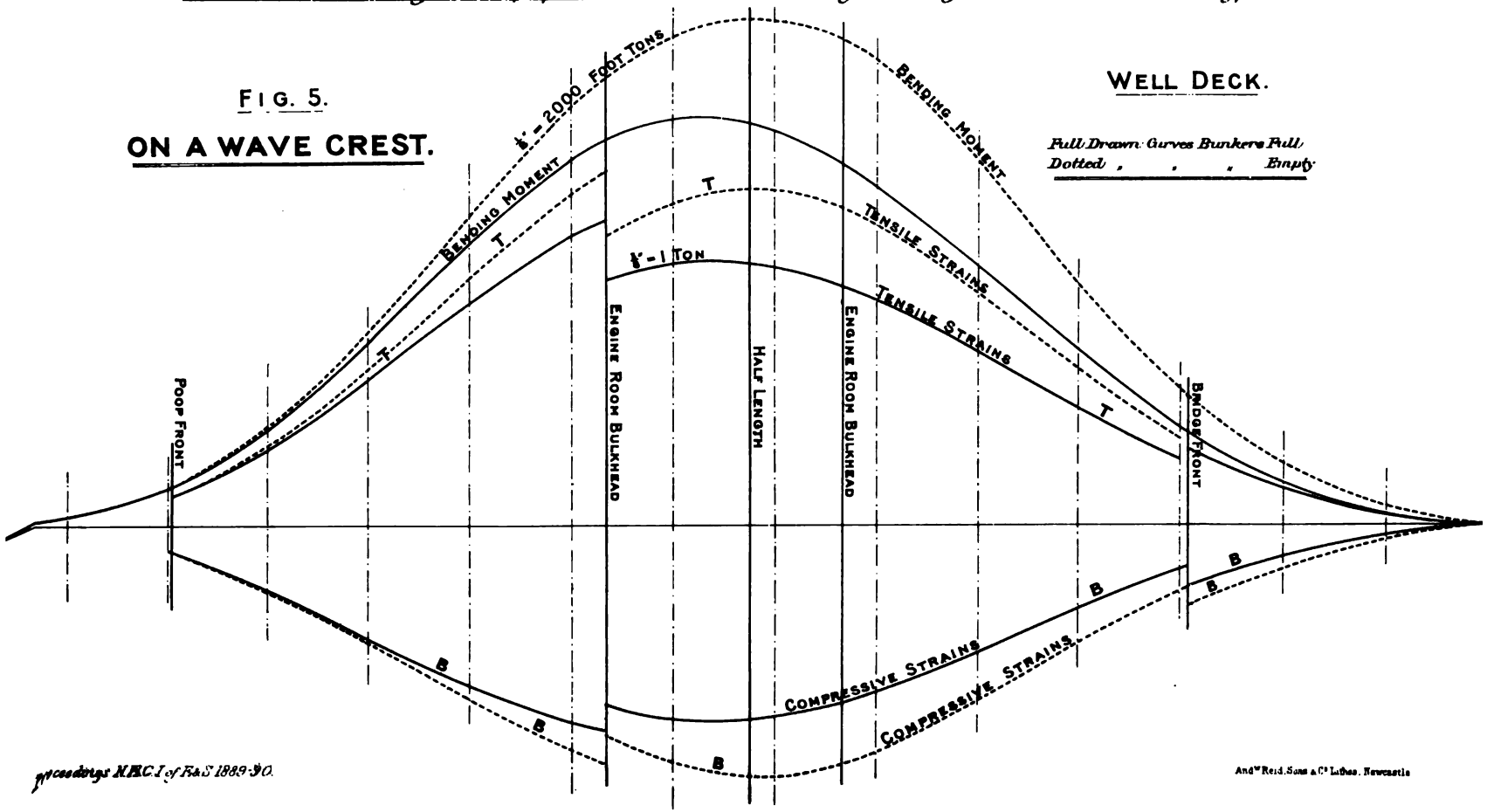
To illustrate Mr. G. Bergstrom's paper "on the Structural Strength of Cargo Steamers of Different Types."

FIG. 5.

ON A WAVE CREST.



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To illustrate Mr. G. Bergstrom's paper "on the Structural Strength of Cargo Steamers of Different Types."

FIG. 6.

ON A WAVE HOLLOW.

WELL DECK.

Full Drawn Curves Bunkers Full
Dotted , , , Empty

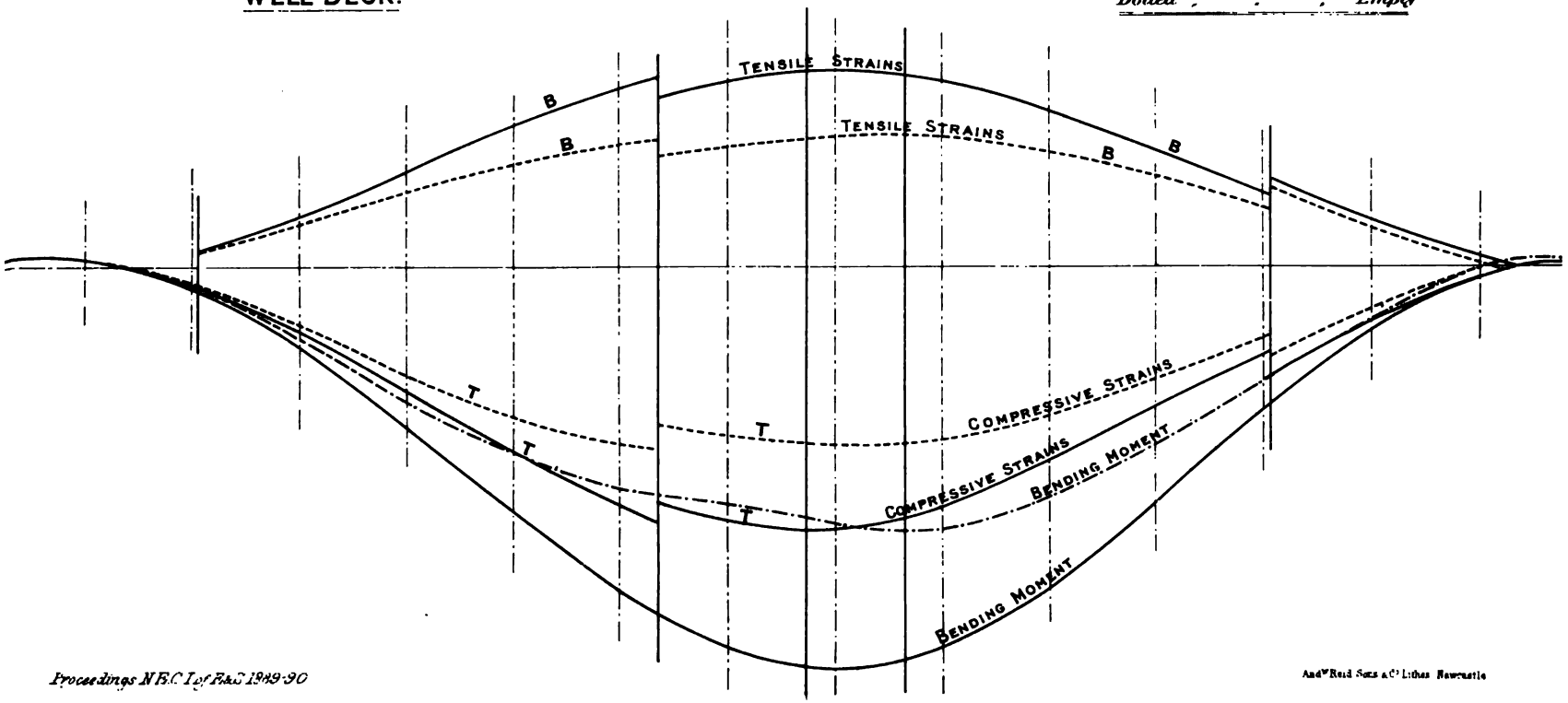

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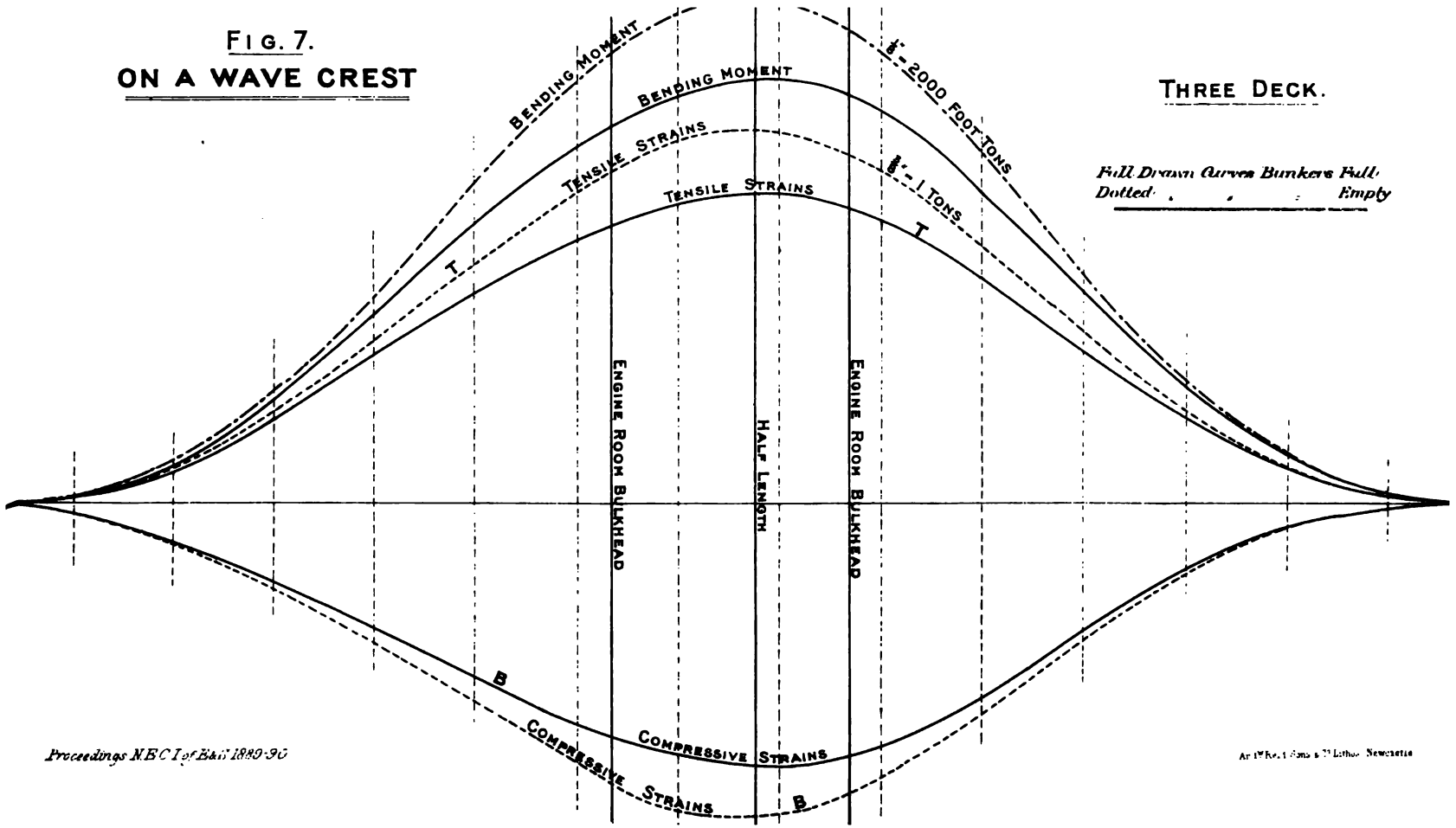
FIG. 7.

ON A WAVE CREST

THREE DECK.



Full Drawn Curves Bunkers Full
Dotted " " " Empty

Proceedings N.E.C.I. of E. & S. 1889-90

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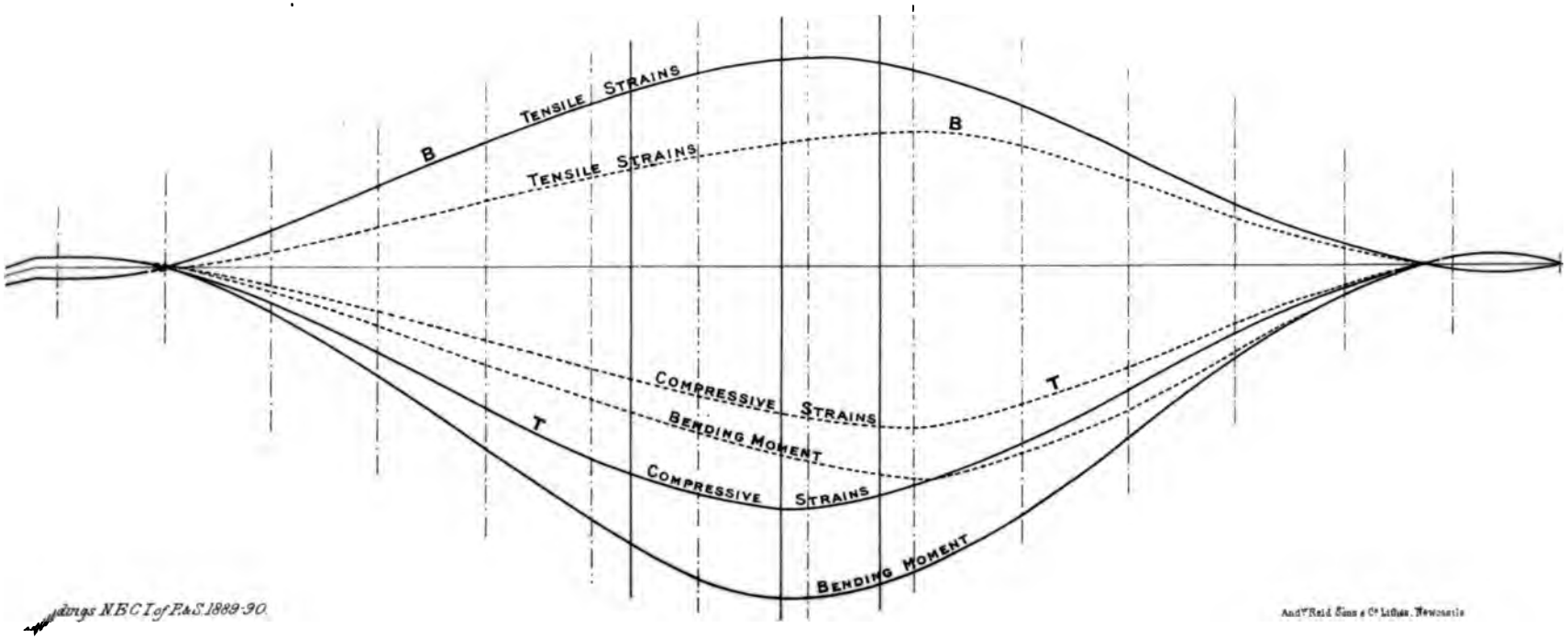
To illustrate Mr. G. Bergstrom's paper "on the Structural Strength of Cargo Steamers of Different Types."

FIG. 8.

ON A WAVE HOLLOW.

THREE DECK.

Full Drawn Curves Bunkers Full
Dotted , , , Empty



Drawings N.E.C.I. of E.&S. 1889-90.

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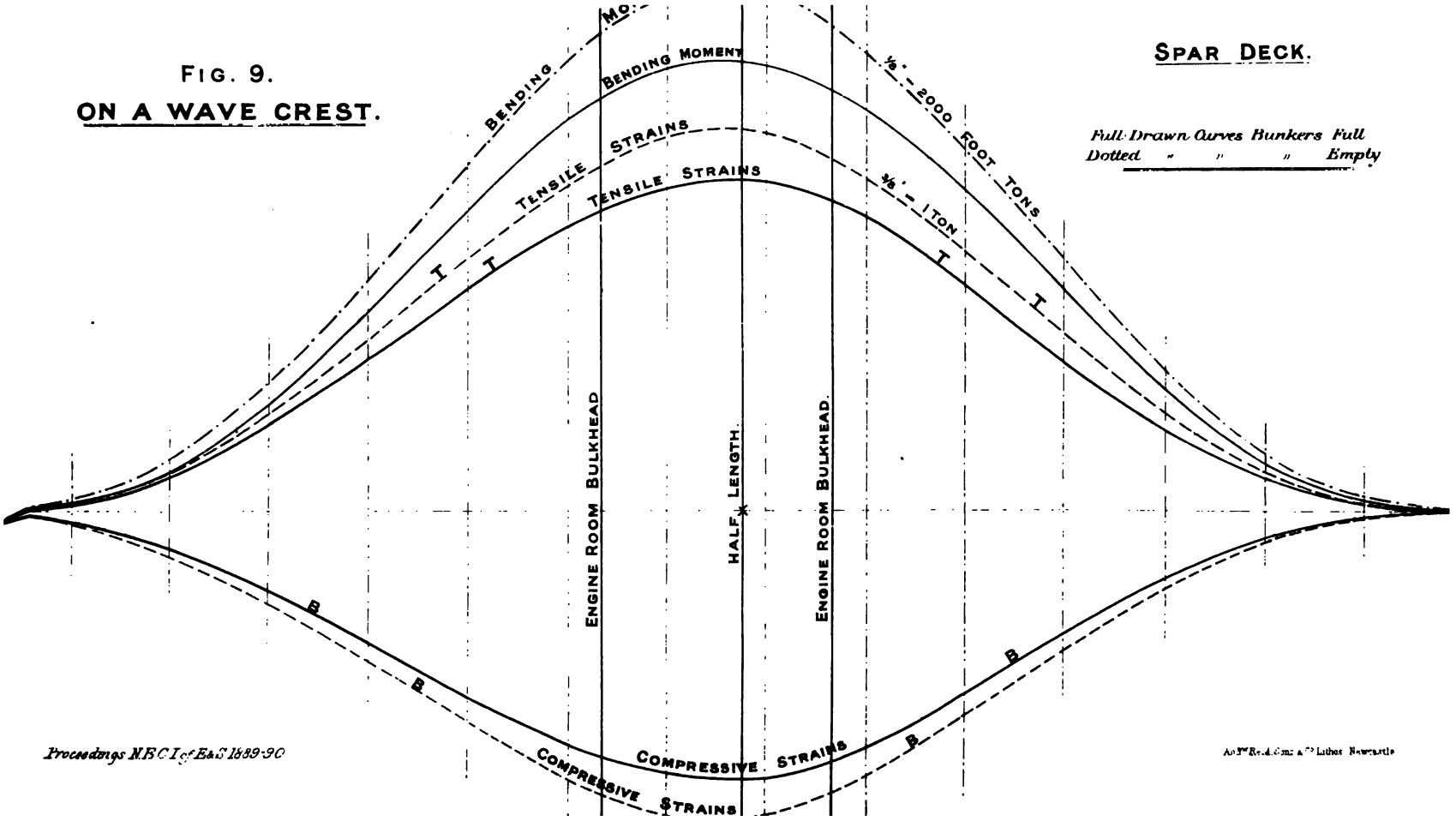
FIG. 9.

ON A WAVE CREST.



Ad. Wm. Reed, Sons & Co. Lithos Newcastle

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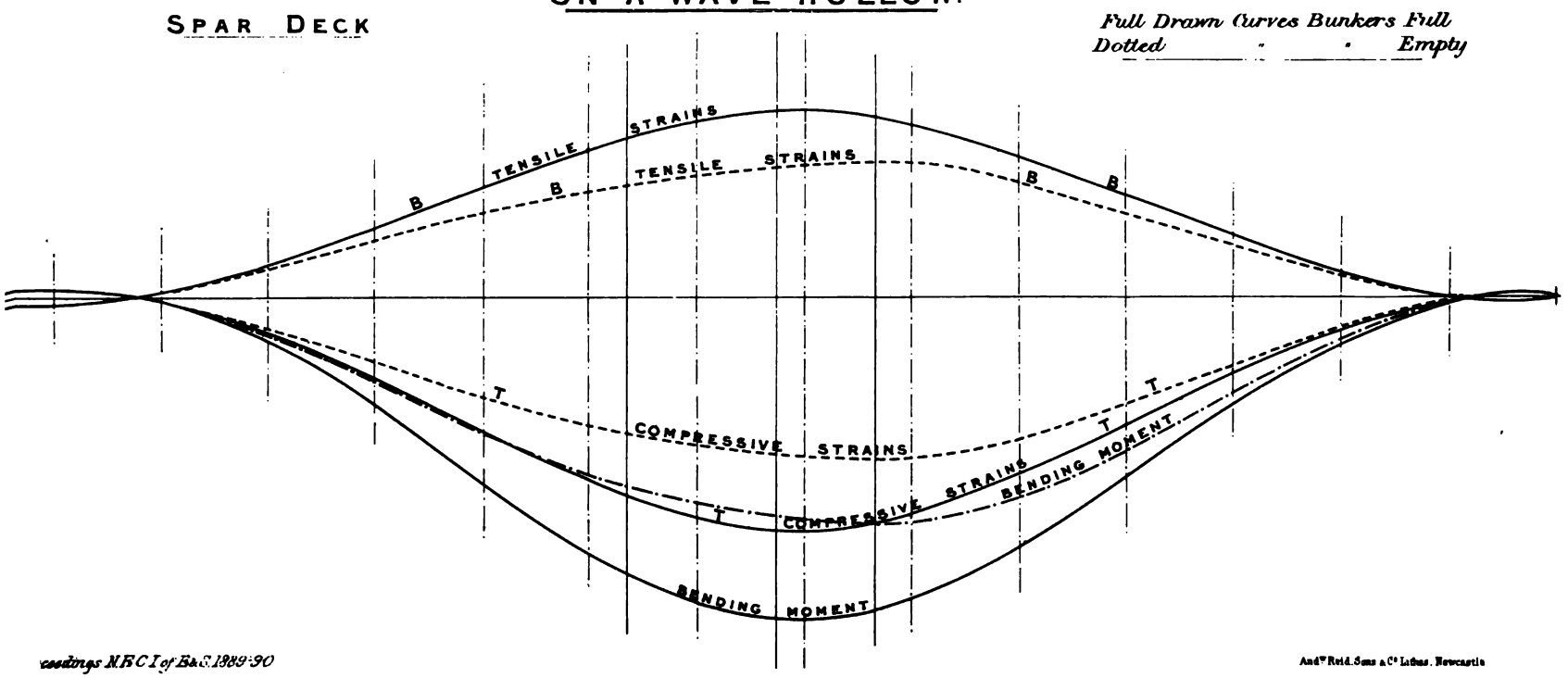
To illustrate Mr. G. Bergstrom's paper "on the Structural Strength of Cargo Steamers of Different Types."

— FIG. 10. —

ON A WAVE HOLLOW.



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To illustrate Mr. G. Bergstrom's paper "on the Structural Strength of Cargo Steamers of Different Types."

FIG. 13.

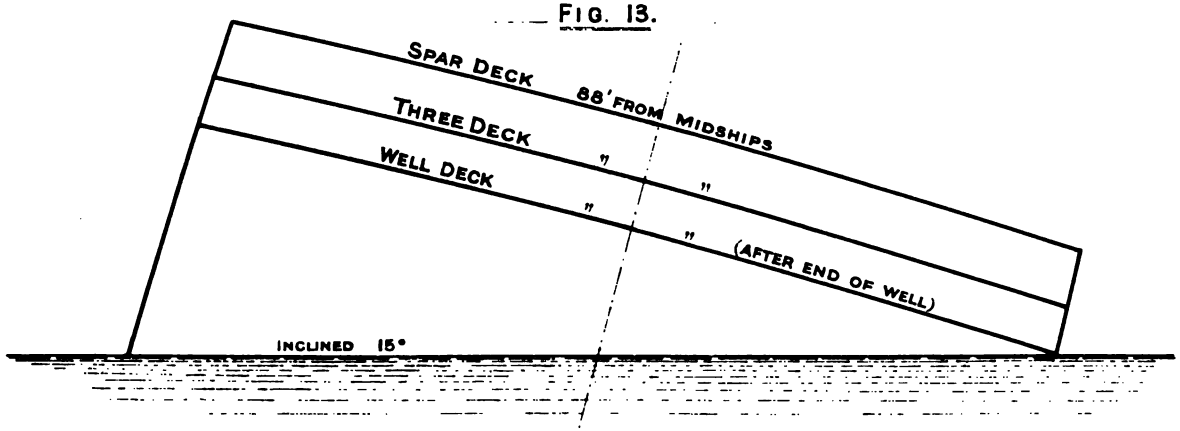
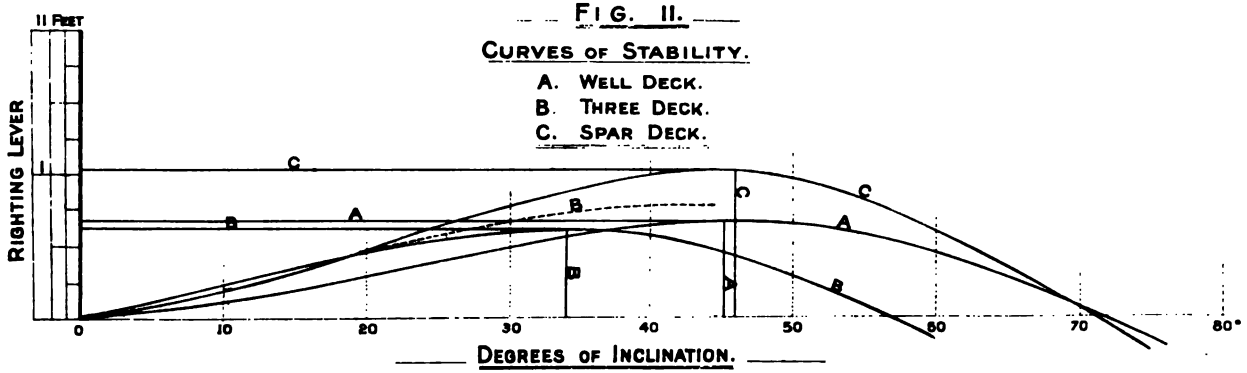


FIG. 11.

CURVES OF STABILITY.

A. WELL DECK.
B. THREE DECK.
C. SPAR DECK.



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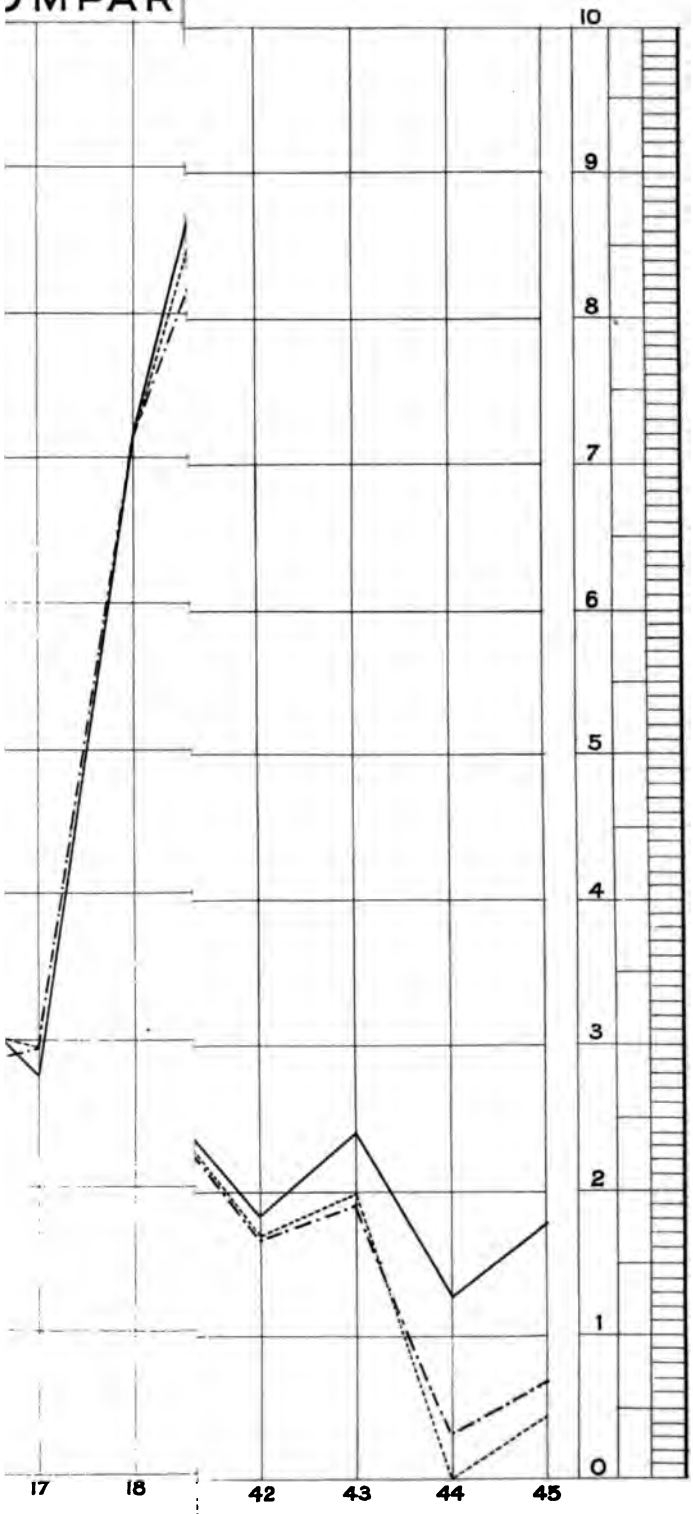

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NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

SIXTH SESSION, 1889–90.

PROCEEDINGS.

EIGHTH GENERAL MEETING OF THE SESSION, HELD IN THE ATHENÆUM, CHURCH STREET, WEST HARTLEPOOL, ON SATURDAY EVENING, APRIL 12TH, 1890.

WM. GRAY, ESQ., J.P., VICE-PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the preceding General Meeting, held in Newcastle, on March 24th, which were approved by the members present and signed by the Vice-President.

The ballot for new members having been taken, the Vice-President appointed Messrs. A. Taylor and G. W. Sivewright to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Courtier-Dutton, W. T., Lloyd's Register of Shipping, 3, St. Nicholas' Buildings, Newcastle-on-Tyne.

Keydell, Amandus Edmund, Lloyd's Register of Shipping, Dundee.

Sheriff, Thomas, Messrs. Robert Mackill & Co., Glasgow.

The VICE-PRESIDENT said the Secretary had received a telegram from the President, at Folkestone, as follows :—"Express to chairman of meeting my extreme regret at not being with you. Detention unavoidable and unexpected. Hope you will have an interesting meeting. Just crossed the Channel." He might also express the regret of Mr. Mudd at not being present, he having been taken with a slight illness that morning. He (the Vice-President) welcomed their friends from Newcastle and Sunderland on this occasion.

NOMINATIONS.

The VICE-PRESIDENT said, in accordance with Article X. of the Constitution, the following gentlemen retired from the Council:—President—Mr. F. C. Marshall; Vice-Presidents—Sir B. C. Browne, Messrs. J. P. Hall and H. F. Swan; Councilmen—Messrs. W. J. Bone, H. Charlton, W. Kilvington, James Readhead, and P. Watts; Hon. Treasurer—Mr. B. G. Nichol.

He had great pleasure in nominating, on behalf of the Council (see Bye-Law 11), the following gentlemen to be balloted for to fill up the vacancies:—President—Mr. Wigham Richardson; Vice-Presidents (three to be elected)—Messrs. Arthur Coote, C. W. Hutchinson, J. H. Irwin, W. Kilvington, and P. Watts; Councilmen (five to be elected)—Messrs. H. Fownes, C. Furness, Maxwell Hill, Johan Johnson, G. E. Macarthy, J. F. Walliker, and T. Westgarth; Hon. Treasurer—Mr. B. G. Nichol.

The SECRETARY (Mr. Duckitt) intimated that it was open to the members to make any further nominations. None were added.

The discussion on Mr. R. L. Weighton's paper on the "Normal Indicated Horse-Power of Marine Engines and Boilers" was resumed.

This was followed by a discussson on Mr. G. Bergström's paper "On the Structural Strength of Cargo Steamers of different Types."

Mr. W. BOYD then read a paper on the "Weight of Machinery in the Mercantile Marine."

ADJOURNED DISCUSSION ON MR. R. L. WEIGHTON'S PAPER ON THE "NORMAL INDICATED HORSE-POWER OF MARINE ENGINES AND BOILERS.

The VICE-PRESIDENT said that at a previous meeting Mr. Weighton had read a paper on "The Institution's Rule for the Normal Indicated Horse-Power of Marine Engines and Boilers," and the first real business on this occasion would be to continue the discussion on Mr. Weighton's paper. He would ask Mr. Fothergill to open the discussion.

Mr. FOTHERGILL said, in response to the invitation to open the discussion, he felt in a somewhat embarrassed position, because to a very large extent he agreed with the author of the paper, and when such was the case it was somewhat difficult to criticise. The N.I.H.P. rule proposed was the outcome of a very able Committee, especially appointed by the Council to investigate the whole question, and this fact made him feel some hesitation in what he proposed to say. The first point was: Is there any necessity for such a rule at present? He did not think there was much argument required on that point. They all admitted the old N.H.P. rule was not only useless but misleading, and thus it became necessary to do something, and he thought the Committee acted very wisely in retaining "horses' power" as the measurement of comparison. It was not the rule he objected to so much as the views expressed by the author relative to its supposed value to the shipowner as a measure of the efficiency of the machinery. On page 175 the author said:—"This rule will prove of great value not only to shipowners, underwriters, and non-technical men generally, but also in the practice of marine engineers." He (Mr. Fothergill) might say at once, as to its value to engine builders he did not propose to make any observation, he thought there were engine builders present who would speak to that part of the question. As to underwriters, he was of the opinion the rule would be of the greatest value as a means of comparative value for insurance purposes, and similarly for classification in Lloyd's Register, and in the same sense to shipowners. If the author had stopped here, he would have fully agreed with him; but he did not, for on page 176 he proceeds as follows:—"Marine machinery may be said to have two kinds of value: (1) value to the owner, and (2) cost to the builder," and, a little lower down this was further emphasised by the following statement:—"It is obvious that the ultimate and only real *value* or *worth* of any machine is its value or worth to its owner or user." He (Mr. Fothergill) fully

agreed with those views, and thought by making a slight addition to factor 1, page 179, the author could not have better defined the shipowner requirement. He proposed to write factor 1 thus:—

"*The cargo carried (or dead-weight) and the speed at which it is carried*," which involved:—

"(*a*) I.H.P."

"(*b*) General efficiency of mechanism and propeller."

(*c*) *Coals consumed.*

Here you clearly have the value of the machinery to the shipowner; but the rule did not give you this, for he failed to see how the rule took into consideration "efficiency of propeller," and he strongly held the "only real *value* or *worth* of the machinery to the user" (namely, the shipowner), as laid down by the author, was its propulsive efficiency, that is, the value of the machinery to propel the ship. They all knew they could get engines from different makers which by the rule would be equal, but in application they would get a material difference in propelling efficiency, and thus he failed to see the value of the rule to the shipowner in the sense the author expressed it. The author justly disagreed with Lloyd's in not including boiler pressure in the rule they had issued, and he fully agreed with the author that any rule to be of value must include boiler pressure; and, on the same argument, he held any rule to be of real value or worth to the shipowner must give some measure of the propelling efficiency and consumption. Why had the author so distinctly included in factor 1, page 179, "efficiency of propeller" as of primary value, if he did not so consider it in the rule? His (Mr. Fothergill's) object was not to condemn the rule, for he thought they had made a very great advance over the old system. His criticism was directed to show the rule had its value, which he thoroughly appreciated, but he thought it a great mistake to let it go forth to the non-technical shipowner that this rule would give him a full measure of any marine engine he proposed to purchase.

To Lloyd's the rule was of great value, for it increased the N.H.P. as compared with the old rules, and thus increased their fees. A very great deal might be said in reference to piston speed, not only in relation to the speed of the piston itself, but in relation to the number of revolutions as affecting the value to the shipowner. Of what value was it to a shipowner as a measure of efficiency to apply the rule based on a certain number of revolutions to engines placed before him by different builders, when as a matter of fact there might be some eight or ten revolutions different between the engines submitted, although in other respects the

engines might be alike? To ensure the engines the rule would certainly be of value. Recognising the rule had its value, and that any rule to be of value must take into consideration piston speed, he considered it was desirable to take the $\sqrt[3]{S}$ and not $\sqrt{S}$, and he thought this was clearly shown by Diagram No. 2, Plate XIX., in which they would observe the revolutions with $\sqrt[3]{S}$ are lower with long strokes and higher with short strokes than in the case of $\sqrt{S}$.

Assuming the boiler to be of normal dimensions, he fully agreed with the author, heating surface was the best measure of its efficiency. In conclusion, he congratulated the author on his very able paper, and if he had not been able to agree with him entirely, yet he was bound to say he considered the rule of value.

Mr. W. Hök said he had reason to believe that the time allotted to the further discussion of this paper was limited, and he would therefore endeavour not to waste more time than he could possibly help. He believed that this formula might possibly represent value of machinery possessing that particular amount of durability assumed in the paper, "if" machinery could not possess that durability unless it worked under the assumed conditions of piston speed and relation between piston speed and stroke, and "if" machinery of equal power could not be of equal value without equal durability. However, if they accepted the assumptions made in the paper that the durability of engines depended on wear and tear—wear and tear on piston speed—and generally guided them by the whole tenor of the paper, they must inevitably conclude that the smaller the piston speed was the greater was the durability, and the greater was the value. Mr. Weighton had compared two engines of equal power, one running 500 feet per minute, and the other 630 feet per minute, and found that their comparative values were as 1,230 and 980. This being so, he had obviously assumed that value varied inversely as piston speed. Therefore, they had a right to conclude, if they introduced another engine of the same power, but running only 398 feet per minute, that the value of that engine was 1,544. But let them merely assume that value was only adversely affected by piston speed, but to an undetermined degree. All the same it inevitably followed that the slower an engine runs the higher was its value, and the quicker it runs the smaller was its value. Why then did the shipowner not go in for less piston speed than used at the present time, instead of always striving towards increasing it? Why was the general tendency towards increasing piston speed, when thereby the value of engines was decreased? Simply because the value of engines was

not affected by piston speed only. There were other considerations of utmost importance, such as weight, for instance, which counterbalanced the so much dreaded effect of the increase of piston speed, and, consequently, minimised, and in some cases, nullified its influence. It might be said that it was so in the Navy, but this counter-effect of weight was also known in the mercantile marine, was occasionally appreciated and made use of by shipowners, and would undoubtedly be more so when competition amongst them increased in severity. It was to be noticed that in Table A, page 195, weight appeared in the denominator, as it should, but it disappeared during the process of transformation in a most unaccountable manner, the reason of which would be very interesting to know. The Committee had made provisions for equal durability of engines, but had they also provided for equal durability of boilers? Was the durability the same for a boiler of 250 lbs. pressure as one of 50 lbs.? If not, he would suggest that, as far as value went, the boiler element be separated from the engine element, as there was really no connection between their respective laws of durability. It would, furthermore, facilitate the solution of the value of machinery when engines happened to be running at different speeds to those proposed by the Committee. It was most extraordinary that the weight of boilers of equal heating surface should vary as $\sqrt[3]{P}$ when most of the heavier parts, such as the shell and furnaces, etc., varied as the pressure itself, and the ends and flat plates as the square root of the pressure. If they also took into consideration that the water might be practically taken as independent of pressure, he did not understand how an expression composed of terms such as P, $\sqrt{P}$, and constant could possibly vary as $\sqrt[3]{P}$. As regarded the weight of engines, he was equally in doubt. The formula implied that by doubling the stroke the weight was only increased 26 per cent., and by using five times higher pressure, only 71 per cent. He would be obliged if Mr. Weighton would further elucidate these two points. He could not see his way to believing that this formula, even if it was proportional to weight, could be proportional to cost. This formula, when it stood for weight, included the water in engines and boilers, which it should, of course, not do when it represented cost, for the simple reason that the ratio of water to total weight was considerable in low pressure, and relatively much smaller in high pressure machinery, the weight of water being in no constant ratio at all to the total weight. In fact, in boilers of 50 lbs. pressure the weight of water was about equal to the weight of the entire boiler. These were his principal reasons for not accepting the wide range of application assigned to this formula.

Supposing now that his views of the unsuitability of this formula representing value were correct, would not the piston speed varying as $\sqrt{S}$ be an improvement, as $\sqrt{S}$ would not handicap the piston speed of large engines to the extent that $\sqrt[3]{S}$ does? Would the formula not give at the same time a truer approximation to weight and cost? But assuming that the formula really represented value, and as such equal durability was required, would it not then be necessary to also vary the piston speed inversely as some function of the pressure due to the probably more rapid increase in the weight of the reciprocating parts for higher pressures, that at the rate of $\sqrt[3]{P}$? Further, he must ask, in consequence of the expression for the relation between the heating surface and the size of the engine being independent of pressure, was a constant efficiency of the boiler really provided for, when no regard was taken of the different conducting power of the heating surface in low and high pressure boilers? Should not the amount of heating surface increase to some extent with increase of pressure in order to ensure constant efficiency? If he was wrong, no harm was done; if, on the other hand, he was right in his conclusions, he begged the members not to adopt this formula before it was modified and improved, and before its range of application was clearly defined, if it was their wish to secure a formula of lasting value.

Mr. J. E. STODDART said they were all very much indebted to Mr. Weighton for the care he had taken in his paper, which explained the horse-power rule of the North-East Coast Institution of Engineers and Shipbuilders. He had not the privilege of hearing the paper read, and only had a very short time to look through it, but there was one point to which he should like to draw their attention. It was the real need for a rule of some value in the place of the obsolete N.H.P. It seemed to him that a rule giving the *Normal* I.H.P. was *not* required, but was likely to lead to complications between the engine manufacturer and the shipowner. I.H.P. should, in his opinion, be ascertained by the usual method of taking diagrams, otherwise the freedom of engine manufacturers would be much interfered with. He would suggest that the new rule be designated *Normal* H.P., and the formula $\frac{(D^2 \sqrt[3]{S} + 3\,H)\sqrt[3]{P}}{100}$ be divided by 6 or some divisor to be decided by the majority of engine makers. Such a rule would enable shipowners and others concerned to make a trustworthy comparison of the various engines and boilers being constructed without leading to the disappointment which would be felt if the I.H.P. on the trial trip did not approach the *Normal* I.H.P. given when the engines were contracted for. Then again, the *Normal* H.P.

obtained by the rule suggested above would be approximately the H.P. used when registering the vessel, and could be adopted for that purpose by the shipowner, thereby preventing some of the complications which would exist if they had *registered* H.P., *Nominal* H.P., *Normal* I.H.P., and I.H.P. He thought the Council should take the matter into consideration, and give them a rule for horse-power likely to be more useful in registering vessels. It had been said that Lloyd's new rule for ascertaining the horse-power had been devised with the object of obtaining larger fees from the shipowners; but it was not so, for he had just worked out the power of a set of engines which were called 300 N.H.P. by the makers, and which were registered 450 H.P. on the old rule, but under the new rule of the Committee of Lloyd's Register the horse-power would be 349 or 101 horse-power less than what would have been charged for under the old rule.

Mr. Fothergill said he referred to the fees of the old rule on nominal horse-power. They could register the engines at Lloyd's to any amount they liked if they would only pay.

Mr. E. Hall-Brown thought they must all admire the ingenuity displayed by their Committee in formulating this rule, and by Mr. Weighton in the paper which had been placed before them. He was sure it afforded them all a good deal of thinking matter, if it had afforded them nothing else. He thought they must all be lost in wonder to find they had such a prodigy in this rule. They found that it was not only a rule for giving the *normal* indicated horse-power; but, also, a correct indication of *cost* to the maker, and of *value* to the shipowner, and finally, when divided by six, it served as an excellent substitute for their old friend *nominal horse-power*; altogether, a handy instrument to have. He was not quite sure, however, that he agreed that the rule fulfilled all the uses claimed for it. For instance, taking first of all what was called the chief aim of this rule, viz., to give the shipowner a means of measuring the value of the engine. He was afraid the value of the engine to the shipowner was a difficult matter to find. They were told in the paper that it could not be given in pounds, shillings, and pence, and with this he agreed. He presumed Mr. Weighton would agree that the smallest engine which would propel a certain ship with maximum of economy would be the most valuable engine to the owner of that ship. If that was the case he did not think this rule gave them the value of the engine to the shipowner. For instance, taking the two engines Mr. Weighton gave. The one had a mean pressure of 28 lbs. at 80 revolutions; the other a mean pressure of 30·6 with the same speed of rotation for the same indicated

horse-power; and of course, the larger engine gave the greater normal indicated horse-power by the rule, and should therefore be the most valuable to the shipowner. He believed the very opposite would be found to be the case in practice. It was very probable that the smaller engine, indicating the same power, would be quite as economical as the larger engine, perhaps more so. The only basis of economy taken into account in the rule was that due to the expansion of steam. Now, there was a point beyond which expansion of steam could only be carried at a sacrifice of economy, and that was not taken into account. If it were argued that no rule could take account of that fact, then no rule could be a measure of value to the shipowner, whatever else it might be. Again, they found that the piston speed was intended to vary as the cube root to the stroke. There was no doubt whatever that this ratio was one that had peculiar qualities. One advantage was that the pressure required to accelerate the reciprocating masses at the end of the stroke was a constant quantity; but for engines used for screw propulsion the revolutions ought to be decided by the screw, and not by the engine. This was an old story of his, and perhaps not generally accepted, but he maintained it as a fact that there must be a speed of revolution of screw, corresponding to maximum efficiency, and as that was not taken into account in the rule given, in that respect also it failed to indicate value to the shipowner. It might give the value, comparatively, of engines for electric lighting and driving purposes, in which the power was not transmitted by a screw propeller or kindred mechanism. He found there was a slight discrepancy in Diagram No. 3, Plate XX., probably it was merely a slip, but he would like it to be put right. In Diagram No. 3 the piston speed was said to be proportionate to the ordinates of the curve; that gave a piston speed of nothing to the stroke of 12 inches, and inertia was given as nothing at the same stroke. To come next to the weight diagram, Plate XXII., he must say that he had derived a great deal of pleasure from that. He thought it was really remarkable how the weights of these engines had arranged themselves along these diagonal lines. He had tried several engines and found they did arrange themselves along the lines, and he believed the correspondence had a sound basis. At the same time he found a great difficulty as to what was included in the weight of the engines; for instance, what was the normal length of shafting? Was there any? Or was the shafting left entirely out of the question? Again, the weight of the boilers and water was a large item. For the same heating surface

the weight of a double-ended boiler was not the same as that of a single-ended boiler, and the weights of water would also vary, unless they could separate the weight of the engine from the weight of the boiler, and put single-ended boilers by themselves and double-ended boilers by themselves; he thought they could not use this rule in estimating the weight of the engine, but if this was done the rule gave a very fair basis for weight. The part of the paper to which most exception must be taken by practical engine builders, was that which related to cost. He believed this rule went forth with the authority of the Institution, and he should not like to think that the Institution lent itself to the statement that engines could be sold at so much per indicated horse-power, even per *normal* indicated horse-power. He was quite sure no one knew better than Mr. Weighton that this was not the case. To make it perfectly clear he would divide the cost of an engine into the two elements, cost of material and cost of workmanship. From the weight diagrams it appeared that the weight varied practically as the N.I.H.P.; therefore, if the cost of material was the same per ton all through for different engines, that element of the cost would be proportionate to the normal indicated horse-power; but the cost per ton of workmanship was a very different matter. The cost of workmanship per ton on a small engine was very much greater than on a large engine. In the case of a large engine, the price of material formed perhaps two-thirds of the total cost, and workmanship one-third. On a small engine this might be reversed. Therefore, the total cost of the engine could not be proportional to the *normal* indicated horse-power, or in other words to the weight, and neither could the selling price. It was not even nearly so. As an example, he would take the comparative prices Mr. Weighton had given in his paper. He gave them the larger engine as £100, the smaller £85·3. He (Mr. Hall-Brown) had taken the trouble to estimate the respective values of these engines, and considered the prices would be more nearly £100 and £93, a difference of 9 per cent., which would be rather a big error in an estimate. He thought upon the whole they might take the rule as a means of arriving at the *normal indicated horse-power* of engines under the conditions specified. Also, by separating the engines from the boilers, the rule formed a good basis for calculating weight; but he certainly thought it was no indication of the value of the engine to the shipowner, of the cost to the builder, or of the price to the buyer.

Mr. A. Leckie said he had no intention of making any remarks upon

the paper when he came into the room, but there were one or two things in the argument which he thought worth taking notice of. There was one point spoken of—the increase of speed during the last few years. Now, up to this time he did not think the speed at which marine engines were driven was higher than used by Messrs. Caird & Co. when he was there twenty years ago. Indeed, an increase of 25 per cent. to 30 per cent. speed to work economically was made forty to forty-five years ago when Wm. McNaught, of Manchester and Glasgow, inventor of the steam indicator, introduced an increase of speed in land engines. In page 188, Mr. Weighton said that "when engines are driven beyond a certain speed of revolution they invariably develop a tendency to vibration." He (Mr. Leckie) thought that not necessarily so, provided that every vibrating part was properly balanced. He held that marine engines, as at present constructed, were not properly balanced, and that was very well shown in the paper that Mr. Hall-Brown read to the Institution about two months ago on his quick running engines. If they balanced the different oscillating or revolving parts of the engine they might run the engines of cargo steamers at a much higher speed, even to double the present speed, without causing any vibration; this he had tested upon engines of centrifugal pumps, of Gwynne and other makers, by weights on the cranks. With these balanced pumps he had driven them up to 1,200 revolutions on salvage work without any difficulty. Another point in the paper required consideration. Boilermakers gave out that heating surface was the proper data to take as the gauge of their power. He had noticed in examining damage to furnaces of marine boilers, from time to time, that when the heating surface was large, as compared with the capacity, accidents were more frequent. The heating surface therefore alone was not the proper measure, but required capacity as well as surface to allow the water and steam quietly to rise up between the tubes, without which the heating surface became a source of danger, causing what the late Mr. Smith, of Messrs. Thomas Richardson & Son's, called very properly, "*suspended ebullition*," the whole of the water rising up off the surface of the plates in the spheroidal state and causing damage to the furnace plates. He therefore thought it was necessary, in calculating the horse-power of the boiler, to take capacity and heating surface combined to get the truth. With the engines themselves, taking the cube root of the stroke, was very well for the merchants, but he did not think it was right for the manufacturer, because the one would give a larger contributory than the other.

Mr. WEIGHTON, in reply to the discussion, said he had to go back to the previous meeting at which there were several speakers on the paper. First of all, with reference to what Mr. Boyd said as to the work of the Committee, it was perhaps well that he (Mr. Weighton) should express what he knew of this matter, and it was chiefly this, that so far as any credit accrued to any particular member of that Committee more than to any other it ought to be to Mr. Boyd himself, and for this reason, that the very inception of the idea of framing a new rule was due to Mr. Boyd, who in his second year's presidential address threw out the suggestion. And not only did he suggest it, but he stuck to it all through, and there was no doubt that had it not been for Mr. Boyd's exertions and guidance the question would never have been brought so far forward as it had been.

The extreme difficulty of the subject was well recognised by the Committee from the beginning, and while it was of course clear that no rule could be produced which would please everybody, some of the members had very grave doubts even as to the mathematical possibility of formulating a rule which would have any pretence to a sound scientific basis. Such having been the state of the question at the beginning he thought the Institution was largely indebted to Mr. Boyd for pushing forward the matter to the issue it had now reached.

Mr. Boyd had told them he used the rule with success in his own office for estimating purposes. Well, he (Mr. Weighton) might say he did the same in the establishment with which he was connected. Whether it was an estimate for an ordinary merchant vessel or for a war vessel he invariably made use of the rule as a check or otherwise, and found it a very useful and a fairly reliable guide. Of course it must be used, like all general rules, with care and discrimination.

It was very gratifying to hear Mr. Patterson's independent testimony as to the value of the rule. He was especially obliged to Mr. Patterson, because he had answered most admirably certain objections raised by Mr. Dyer in a paper on the subject read before the Institution of Engineers and Shipbuilders in Scotland last year. The allegation that the rule would stereotype a certain class of engine was particularly well dealt with by Mr. Patterson.

With regard to the factor $\sqrt[3]{P}$ it was interesting to hear that by a slight variation in the assumed terminal and back pressures, Mr. Patterson found it to represent the mean pressure even more closely than was claimed for it in the paper.

In reply to Mr. Sandison he had to say that he took the heating surface to include the furnaces and combustion boxes above the level of the fire bars and bridges, the back tube plates and the tubes, but not the front tube plates. Of course it did not much matter whether the front tube plates were included or not. So long as they were either always included or always omitted, the justness of the comparison of different boilers would not be affected. He had, however, in all his calculations omitted the front tube plates, but if the rule were to be generally used the heating surface would of course require to be strictly defined.

Mr. Walliker had spoken of the rule from the point of view of Lloyd's. There did not appear to be much to be said from this point of view with any profit. It *did* seem, however, an extraordinary thing that a body such as Lloyd's, having technical and scientific advisers, should issue a rule dealing with steam machinery, which rule took no cognisance of steam pressure.

He had now to deal with the speakers of that night and, parenthetically, he would just like to say that he felt very glad that the discussion had been adjourned from last meeting, because some of the speakers of that night had raised questions which gave him a further opportunity of explaining misapprehensions which evidently existed in some minds as to the meaning of some parts of the paper. At the same time he must confess he was surprised at the way in which he had been misunderstood. He had thought he had specially guarded against such, and had in fact repeated himself on several points till the paper grew to such an inordinate length that he had to abridge other points. However, he would now endeavour to make sure that the scope of the rule on the points raised should not be further misunderstood.

First, with regard to his friend Mr. Fothergill. He was pleased that Mr. Fothergill agreed generally with the spirit of the rule. When he came, however, to speak of coal consumption and propeller efficiency he showed a strange non-acquaintance with the essentials of the paper. So much was this the case that he (Mr. Weighton) feared the great length of the paper had been responsible for some parts having been overlooked.

Mr. Fothergill proposed to make an addition to factor 1, page 179, in the shape of coals consumed. He seemed to be under the impression that the coals had been omitted. He would find them in their proper place, in factor 4, page 180, and also in Table A, page 195. Next, as to the efficiency of the propeller, which was the chief point raised by Mr.

Fothergill. He asked, "Why had the author so distinctly included in factor 1 efficiency of propeller as of primary value if he did not so consider it in the rule?" The answer to that question was, because it was impossible to include it in any rule, as was distinctly stated more than once in the paper. And even though it were possible to include the propeller efficiency, he did not think it would have been wise to do so, because the question of engine tear and wear would have been thereby necessarily ignored. The revolutions corresponding to the maximum efficiency of the propeller might be so high as to entail an enormous amount of wear and tear on the engines, or they might on the other hand be so low as to prevent the engines giving out the amount of power their length of stroke warranted them giving. But in addition to all this it must be borne in mind that propeller efficiency was by no means measured by number of revolutions alone. The lines of the vessel, her speed, the diameter, pitch, and surface of the propeller as well as the shape of the blades all entered into the question of propeller efficiency, and of course it was hopeless to think of including all these elements in a rule.

Mr. Fothergill went on to say [page 227], "His criticism was directed to show the rule had its value which he thoroughly appreciated, but he thought it a great mistake to let it go forth to the non-technical shipowner that this rule would give him a *full measure of any marine engine he proposed to purchase*." The italics were his (Mr. Weighton's) for the reason that he took these words as expressing Mr. Fothergill's sole objection to the paper—he did not object to the rule, he objected to what he understood was claimed for it. And this also expressed Mr. Hall-Brown's objection as regards the use of the $\sqrt[3]{S}$—at least so far as he had understood Mr. Hall-Brown.

Now, if the above was the meaning generally gathered from the paper he must have expressed himself very imperfectly, because he had intended it to be clearly understood that the rule was *not a full measure* of value, as the following quotations from his paper would show, viz.:—

[Page 177.] "Apart, however, from the question of the possibility of introducing such arrangements, it is to be distinctly borne in mind that no elements beyond size of engines and boilers, and working pressures, can *possibly* be included as factors in any general rule."

[Page 181.] "If a rule could be framed which would embody all these factors, and embody them in such a way as to give each its due and proper influence in determining the result, it would be a *perfect* measure

of value in every case, however varied the factors or conditions might be. But this is clearly impossible, both from a mathematical and a mechanical point of view."

"In order to reduce the problem to dimensions which will enable it to be dealt with at all, it is necessary to make certain assumptions."

[Page 182.] "The uniformity or normality of those factors which depend upon the dimensions of the cylinders, the stroke of pistons, the heating surface of the boilers, and the working pressure, is secured (in a manner to be presently explained) by the *form* of the rule itself. The uniformity of factors or conditions, *other* than those depending upon dimensions and pressure, cannot possibly be secured by *any* rule, formula, or method, be it ever so complicated."

[Page 183.] "3. That value depends on many factors which no rule can embody, and that the only factors which it is possible or necessary to take into account are the dimensional elements of the engines and boilers, and the working pressure."

[Page 184.] "Variation in efficiency of the steam cannot be taken into account as a factor in any general rule such as this one. Such variation is a most important factor in the value of steam engines, but it is undoubtedly outside the pale of exact estimation by any combination of known dimensions, areas, pressures, or proportions. It falls within the category of the variable coefficient at the end of Table A, page 195, and as such is to be valued by other means than pure mathematics."

[Page 195.] Table A. "Efficiency of mechanism and propeller, durability not due to speed of revolutions nor to boiler duty, coal consumption not due to expansion," etc., etc., are all shown as being outside the rule and as "forming a variable coefficient depending upon causes not susceptible of exact measurement, but probably fairly uniform for the individual manufacturer and for any one type of machinery."

In the face of these statements he did not understand how anyone could conclude that the rule was put forward as a "full measure" of the value of any marine engine. In the first place the rule did not give, and was not claimed to give, a full measure of the value of any marine engine, and in the second place no rule could possibly give any such thing.

What the rule claimed to give, and what the Committee considered it did give, was a *measure of the value of any marine engine so far as dimensions and pressure could have value*, and no more.

The term *value* was introduced into the paper for a very special purpose. It was introduced for the purpose of justifying the particular

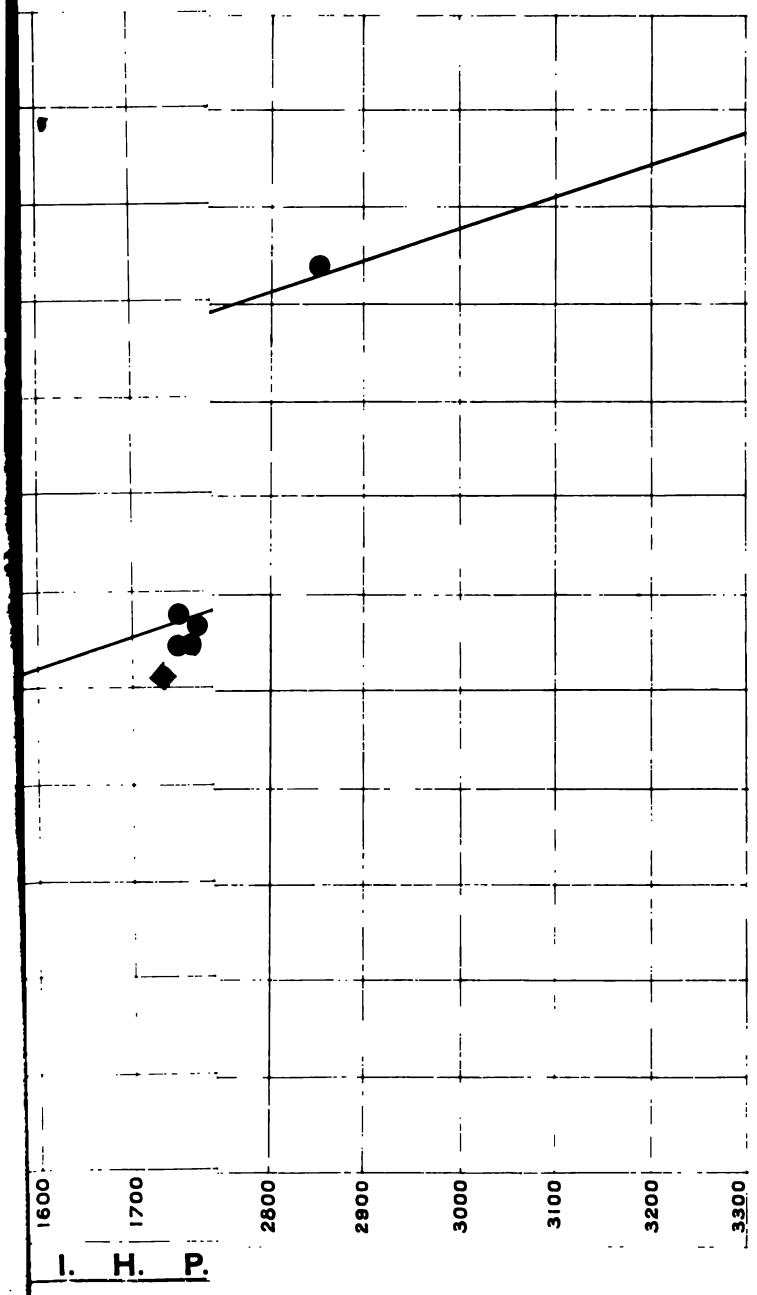
form which the rule had had given to it, for the purpose of explaining the principle upon which it was framed. It was not introduced for the purpose of proving that the terms of the rule were coextensive with value, that they comprehended all the factors which affected value.

How otherwise than on the basis of value to the owner could the presence in the rule of the low pressure cylinder alone, to the exclusion of the high and intermediate pressure cylinders be justified? How otherwise than on the basis of value could the limiting of the speed of piston to an amount depending on the length of stroke ($\sqrt[3]{S}$) be justified? How otherwise could the proviso of a constant coal consumption for a constant pressure ($\sqrt[3]{P}$) be justified?

These were the primary reasons why the term *value* was introduced at all, but having been introduced it became necessary to make sure what portions—so to speak—of the whole value were to be included and dealt with by the rule. Hence the necessity for stating—as was done in the paper—all the factors which determined value, not for the purpose of including all, but for the express and special purpose of showing how many of these factors must of necessity be left out altogether, and how many could be taken account of in the rule.

Mr. Hök was the next speaker, and from the major part of that gentleman's remarks it was evident that the question of "durability" occupied in his mind an exaggerated importance. So much was this the case that he seemed to have persuaded himself that "durability" was the sole basis of the rule. For example, Mr. Hök said "Mr. Weighton had compared two engines of equal power, one running 500 feet per minute and the other 630 feet per minute, and found that their comparative values were as 1,230 to 980. This being so, he had obviously assumed that value varied inversely as piston speed." Now, in the first place, the one engine was not running at 500 feet, but at 480 feet (80 revolutions and 3 feet stroke), and in the second place, the comparative value was not assumed as being inversely as piston speed. It was assumed as proportional to N.I.H.P., *i.e.* if the first engine is 1,230 N.I.H.P. the second one will be $\frac{1,230 \times (54^2 \sqrt[3]{42})}{(62^2 \sqrt[3]{36})} = 980$. Piston speed had nothing whatever to do with the value of these engines, but length of stroke and diameter of cylinders had everything to do with it. Mr. Hök went on to say that "it followed that the slower an engine runs the higher was its value, and the quicker it runs the smaller was its value." Now, wherever Mr. Hök got this wonderful proposition, he

tion's Rule for



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certainly did not get it from the paper. If this were true then it would follow that the engine which did not move at all would be of infinite value! Instead of inculcating such ridiculous absurdities as these, the paper expressly showed that value *varied directly as piston speed*, in as far as piston speed was allowed to increase as stroke increased ($\sqrt[3]{S}$).

Mr. Hök had evidently failed to master one of the fundamental provisoes upon which the rule was based, viz., that it was impossible to rate the values of engines which had varying degrees of durability. Any rule which attempted this ought certainly to be looked upon with suspicion, for who was to say what was the value of degrees of durability? All that the rule did in this connection was to give the horse-power which would be attained when *durability was uniform and equal, so far as this uniformity could be secured by speed of revolution*, and under these circumstances each horse-power so obtained would be of the same value, whatever the size of the engines. Hence the rule only predicates value when durability is uniform, and says nothing about value or anything else when durability is variable. Engines when working may have any amount of piston speed, but the rule when applied to them takes no cognisance of their several piston speeds, it only takes cognisance of the dimension which alone should determine piston speed, viz., length of stroke.

As to the reason for the disappearance of the weight factor in Table A, which seemed to puzzle Mr. Hök, he begged to refer him to the paragraph on page 192, headed "Weight," and to the proposition which followed in italics.

The comparative durability of boilers working at 250 lbs. and at 50 lbs. was a question which, viewed in all its bearings, would be a difficult one to determine, and indeed such a question had not concerned the Committee. They did not set themselves to produce a rule which would involve such an indeterminate factor as the above; all they were concerned about, in regard to the boilers, was to secure a uniformity of demand upon each square foot of the heating surface, let the pressure be what it might, and this he contended was amply sufficient. The same remark would apply to Mr. Hök's proposal to allow an increase of heating surface to an increase of pressure. In addition, such a proposal as the latter would inevitably introduce complications and refinements incompatible with the usefulness of any rule.

As to the influence of pressure upon the weight of boilers, and in reference to the remarks in the paper on page 192, hinting at analytical or

[illegible]

stroke was generally associated in any one engine with a large diameter, and *vice versâ*, the product $D^2 \sqrt[3]{S}$ gave a very fair index of weight, and this he submitted was powerfully corroborated by the weight diagram.

With respect to the water in the boilers, all he had to say was he did not agree with Mr. Hök, that the ratio of water to total weight varied to such a degree as to vitiate his conclusions, and in support of this he would append an additional diagram (see Plate XXXII. A) showing the merchant class of machinery as on Plate XXXII., but without water. From this diagram it would be seen that the spots followed the straight line with practically as great general regularity as when water was included.

Mr. Stoddart's proposal to divide N.I.H.P. by 6 would be found suggested in the end of the Report appended to the paper, for use in cases where a comparison with the old nominal H.P. was desired. There was no doubt a good deal to be said in favour of this proposal, but on mature consideration the Committee had concluded that there was more to be said against than for it. As to the name, Normal H.P. was altogether too like Nominal H.P., and the initials of both were identical. He must confess that this matter of an appropriate name had been a matter of great difficulty with the Committee, and they could have wished it to have been shorter while equally descriptive.

Mr. Hall-Brown's criticism was nothing new in the history of this rule, in so far as failure to grasp the drift of some parts of the subject was concerned, but the way in which Mr. Hall-Brown evolved his views on the matter was certainly new and peculiar to himself. Mr. Hall-Brown began under the evident impression that the rule afforded nothing except "thinking matter," but as he proceeded it transpired that it had afforded (to him at least) a "great deal of pleasure" in respect of the weight diagram. He also did the rule the honour of calling it a prodigy, but Mr. Hall-Brown must be very difficult to satisfy, because from his subsequent remarks it appeared the rule failed to represent a tithe of what he expected it should have represented, and instead of being content when he found something prodigious, Mr. Hall-Brown would be satisfied with no rule which fell short of the miraculous. The rule which would correctly involve all the possible factors which affect the ultimate worth of the propelling machinery of a steamship would most assuredly partake of the nature of the miraculous. Where the notion came from that the N.I.H.P. rule involved all these factors was a mystery to him (Mr. Weighton), it certainly was not found in the paper nor in the report—the very opposite being stated time after time in the paper.

He would deal with Mr. Hall-Brown's points individually.—First, he agreed with Mr. Hall-Brown that the smallest engine which would propel a certain ship with maximum economy would be the most valuable engine to the owner of that ship. But he certainly did not agree with him that the smaller of the two engines he refers to would be the more valuable one to the shipowner. On the contrary, he was absolutely certain that if the engines were similarly proportioned and similarly built the larger engine would be of more value than the smaller one, and moreover that the amount of difference would be practically measured—other things equal—by the difference of their respective N.I.H.P.

Next, Mr. Hall-Brown proceeded to point out that there was a limit beyond which expansion of steam was the reverse of economical, and that as the rule did not take account of this fact it could not give the value to the shipowner in cases where the expansion was carried beyond the economical limit. Certainly it did not represent value in this sense, nor was it ever intended that it should. As well might it be objected to on the score that as it did not take account of a possible flaw in the crank-shaft it could not represent value to the shipowner, whatever else it did. The rule represented value as far as dimensions of engines and boilers and steam pressure were concerned in value, and no further; nor was it claimed for it that it could possibly represent more. If it represented (as Mr. Hall-Brown conceded it might do) "the value of engines for electric lighting and driving purposes," that was exactly the kind of value which it was claimed it *did* represent, and so his case was granted. Then came the inevitable question of propeller efficiency again, the same as raised by Mr. Fothergill, and his answer to that gentleman must suffice for Mr. Hall-Brown.

Both Diagrams 3 and 4, Plates XX. and XXI., were, as mentioned in the text, merely comparative, and gave no *absolute* measures of effect either above or below the base line. All that was essential for comparison was, that at any given stroke—in this case at 42 inches—they should show *equal* effects. The curve which had the most angle upon it was started from the base line at the shortest stroke taken account of (12 inches) for the sake of saving space in the diagram, and getting it within convenient dimensions in the Transactions. If it were to represent absolute effects, it ought, of course, to start from zero stroke instead of from 12 inches stroke.

It was, of course, well known that the weight per foot of heating surface of double-ended boilers differed slightly from that of the single-ended variety, and also that the weight of water carried would vary

somewhat in passing from the one variety to the other. It was due to this, amongst other obvious reasons, that he had recommended in the text (page 194) that the engines and boilers should be dealt with separately in questions affecting weight and cost. As regarded the shafting, he had simply included all the shafting in each case given on the weight diagram, and the reason why the spots did not range *exactly* in a straight line, he surmised might be largely due to the fact that the lengths of shafting varied a good deal in the several cases, and that both double and single-ended boilers were included.

Then as regarded Mr. Hall-Brown's objections in the matter of cost. He would first of all beg to refer him to the paper, in which he would find it stated that the rule could only be used for the purpose of finding a *basis* cost. It could therefore not be used for finding a final and absolute cost.

Mr. Hall-Brown, in his (Mr. Weighton's) opinion, made a great deal too much of the variation of cost per ton of material due to variation in size. Of course the merest tyro in estimating knew that size was most important in affecting cost per ton; but if he consulted the paper, on page 194, he would find the application limited, amongst other things, to engines "not differing enormously in size," and the instances he (Mr. Hall-Brown) cited in which two-thirds cost of material might be changed into one-third, would most certainly be included in the category of "enormous difference" in size.

In the numerical example, he considered Mr. Hall-Brown most certainly wrong in his estimate of the relative costs of the two engines referred to. Had he not omitted to note that the first engines were to work at 170 lbs. pressure, while the second were limited to 150 lbs. pressure? The rule was admitted by Mr. Hall-Brown as a good basis for weight. Well, on this basis the weight of No. 1 engines would be 210 tons without water, and on same basis No. 2 engines would be 179 tons without water. Now, his (Mr. Weighton's) estimate gave, of course, the same cost per ton of material for both engines, while Mr. Hall-Brown's estimate allowed for No. 2 engines nine per cent. more cost per ton than for No. 1 engines. He would ask how could this great difference in cost per ton possibly be justified in the case of engines differing so little in weight as is represented by the difference between 210 tons and 179 tons?

Mr. Leckie said that vibrations in marine engines could be entirely prevented by balancing of moving parts. The revolving parts could certainly be perfectly balanced so as to prevent any tendency to vibration due to the cranks, but the reciprocating pieces could not possibly

be balanced in the same sense, in engines of the marine type which had all the reciprocating parts on one side of the crank-shaft.

If Mr. Leckie would calculate the momentum of the moving parts in the case of the centrifugal pump engines to which he referred, he would find that it was small compared with that of large marine engines, even when the pumps were running very fast indeed. Mr. Leckie thought that, in order to get at the power of the boilers, it would be better to take heating surface and capacity combined. With this view he (Mr. Weighton) did not agree for reasons given in the paper, but for purposes of weight calculation alone, when the boiler proportions were unusual to any great extent, he had found that a nearer approximation was obtained by taking a mean of the heating surface and the product of the diameter squared and the length, for the H.S. in the rule; that was to say, instead of the H.S. of the rule, take $\frac{\text{H.S.} + D^2 LN}{2}$, D being diameter of boilers, L being length of boilers, and N being number of boilers in the ship.

The VICE-PRESIDENT said they had had a very interesting discussion on Mr. Weighton's paper. He did not profess to be an engineer; but having heard the arguments, both *pro* and *con*, he did profess to draw something like a common-sense conclusion, and from what he had heard of this discussion he had come to the conclusion that the paper was a very valuable one. It was extremely desirable that they should have some pretty correct system of determining the horse-power. Lloyd's had been referred to. Well—it was known in Lloyd's book—in olden time they could call a vessel of any horse-power they liked. He had in mind two compound engines made at the same works not many miles from where they were. The two cylinders were 33 inches and 61 inches, and the stroke was 33 inches. He believed these engines were sold as 140 horse-power nominal. On referring to the two vessels for which they were supplied, he found that in Lloyd's book one was 99 horse-power—for a purpose they all understood—and the other was called 250 horse-power. Anything more misleading than that they could not conceive; and if the reading of this paper would tend to the doing away with such anomalies they would all be thankful indeed to Mr. Weighton. He had very much pleasure in moving that the best thanks of the meeting be given to Mr. Weighton.

The vote was given by acclamation.

DISCUSSION ON MR. BERGSTRÔM'S PAPER ON "THE STRUCTURAL STRENGTH OF CARGO STEAMERS."

Mr. F. J. TREWENT, who opened the discussion, observed that they were much indebted to Mr. Bergstrôm for his very valuable paper, which must have given him considerable thought and calculation. He was sorry he was not present at the last meeting to hear it read. He did not wish in any way to depreciate the paper, but would try to carry out Mr. Bergstrôm's idea, as expressed in his last paragraph, where he said he "hoped some more information might be added during the discussion." He had not had much opportunity of looking into this paper, but in glancing it over he was very much surprised at the results that he saw in the tabulated statement at the end (see page 223). In fact, so much surprised was he that he looked a little further into it to see whether Mr. Bergstrôm had taken all the facts into account. The writer said on page 215 that "it was not his intention to advocate any of these types," that was to say, one type of ship in preference to another. He thought he had, however, fallen into the error of putting the three-deck ship and the spar-deck ship forward in a less favourable light than they deserved. They all knew this neighbourhood (the Hartlepools) was the birthplace of the well-decker; but at the same time he thought the other classes of ship should have all the credit to which they were entitled. He had nothing at all to say against the well-deck ship, but admitted at once they were the most economical ship they could build. Of course, some people preferred to spend a little more money, and went in for a class of ship that could go without any difficulty all round the world. Mr. Bergstrôm also stated on page 215 "to effect a fair comparison between different types of vessels, three things must be taken as constant—the length, beam, and carrying capacity." He did not see why these three should be taken as constant, for in his view, the only constant was the dead-weight carried, and if they decided on the best dimensions for the well-decker, then they had simply to decide on the best dimensions of the three-deck ship and the spar-deck ship to carry the same cargo. He thought the three-deck ship had not been quite fairly treated on page 216 with regard to the stability. The writer had assumed that in the three-deck steamer the erections should be "omitted, as the ends, though closed with bulkheads, were not perfectly water-tight." He thought in the three-deck ships they might assume these bridges were water-tight. In many cases, in three-deck ships, bridges were built with water-tight bulkheads; but whether that was so or

not, with iron doors in the bulkheads, they were, for all practical purposes, water-tight. On the stability curves in the diagrams illustrating the paper they would see that the well-deck ship had the longest range of stability, and the three-deck ship only reached to about 70 degs. If that bridge was a reasonably water-tight structure, instead of the range of stability of the three-deck ship being 57 degs. and the maximum righting lever 7½ inches, there would be an increase range to 76 degs. and a maximum righting lever of 9¼ inches. If they went further and considered that both the poop and forecastle were water-tight structures, they would immediately raise their range of stability of the three-decker to about 85 degs. and their maximum righting lever to 12 inches at 57 degs. They would therefore see, by taking the erections into account, they greatly extended the range of stability of the three-deck ship over the raised quarter-deck ship, and also the length of the righting lever, which was exactly the opposite of what had been given in this paper. The same naturally applied to the spar-deck ship. Their friend (Mr. Bergstrôm) had taken the length of the bridge in the spar-deck ship very short. In the table, page 223, they would see that the bridge in the spar-deck ship was only 20 feet. There was no reason why it should not be the same length as in the three-deck ship, but even with the bridge of 20 feet they would have a longer range of stability and a greater righting lever than given in the table. With regard to the strains, the table, page 224, pointed out that the strain on the wave crest with bunkers full was, in well-decker, 4·22; three-decker, 5·03; spar-decker, 5·31. He thought he was right in assuming that in the three-decker, the bridge itself had been omitted altogether as part of the strength of the ship; in the well-decker the bridge had been taken into account. If taken into account, the tensile strain on the first case was reduced for the three-decker from 5 tons to 4·1 tons, which was below that of the well-decker, and the compressive strain also reduced from 4·27 tons given in the paper to 3·32 tons. The same applied on a wave crest with bunkers empty. The tensile strain would be reduced from 6 tons to 4·9 tons, and compressive strain from 5·1 to 3·92. In most of those cases the strains were below the strains on the well-deck ship. The same thing applied right through on the wave hollow with the bunkers full and empty. Also on the spar-deck ship there was not the slightest reason why that bridge should not be taken into account. If they took the bridge into account in three-decker and spar-decker they would get on the diagrams a break in the curve the same as they had in the curve of the raised quarter-deck ship; but as Mr. Bergstrôm said in his paper with regard

to the well-deck ship that where the breaks occurred it could be compensated for and was compensated for in well-deck ships. The same could easily be done in three-deck and spar-deck ships and was continually being done. In the table, the weights were given of the hull of the three vessels. He said in altering the dimensions they could reduce the weight of the three-decker. If they took 10 feet off the length and increased the beam they would get a more stable ship and save about 15 tons in the three-decker, and 25 tons in the spar-decker. After referring to Prof. Jenkins's paper read at the Institution of Naval Architects as opening a new and interesting chapter on strains, he (Mr. Trewent) said they must not accept these calculations as actually the strains borne by the ship, but simply as a basis to compare the strength of one ship with another. The actual strains might be more or less dependent upon the loading of the ship and waves encountered. He would only say in conclusion this was a very valuable paper, and he thought great praise was due to Mr. Bergstrôm for the very able and careful manner in which he had treated the subject.

Mr. COURTIER-DUTTON said that he rose with some diffidence, as he had only just been elected a member of that Institution, an honour which he very much appreciated. He did not intend to enter into the merits of the different types of vessel referred to by Mr. Bergstrôm, for so many people had their own favourite type, who were equally right from their own point of view, that this seemed to be a question which, like the well-known "brook," was destined to go on "for ever." He wished merely to refer to the question of freeboard touched upon by Mr. Bergstrôm, and in which he (Mr. Courtier-Dutton) had a special interest in connection with his work as a Surveyor to Lloyd's Register in the Newcastle district. On page 219 Mr. Bergstrôm stated:—"Next comes the question of freeboard of the three types, and the figures given in the table have been worked out as near as possible from the present freeboard tables. The writer is not prepared to argue the question of freeboard in the present paper, but will not pass over so important a factor, affecting as it does the stability and, perhaps more directly, the straining on the vessels, without a few remarks. As will be observed in Figs. 2 and 3, Plate XXIV., the main deck is taken as being of wood, and had iron been substituted an allowance in the freeboard of 2½ to 3 inches would have been granted, and consequently the vessels could have been built that much shallower, still carrying the same cargo. This diminution in freeboard and depth would certainly have decreased the stability and, equally cer-

tion increased the principal or longitudinal strains on the vessels. From this it appeared that Mr. Bergström wished them to understand that the mere substitution of a wooden deck for an iron one had the effect of largely reducing the longitudinal strains, increasing the stability, and increasing the carrying capacity. That any tables of freeboard should bring about such a result was a statement it was difficult to treat seriously, and it was a very poor recognition of the valuable time and trouble given by the gentlemen who framed these tables, and of whom they had so able a representative in their respected Vice-President. If Mr. Bergström looked more carefully into the tables he would find that where an iron deck was fitted, the freeboard, after deduction of the thickness of a supposed wood deck, was measured not from that supposed wood deck, but from the iron deck; the resulting load-line, the reserve buoyancy, the carrying capacity, and the stability, being therefore practically the same in either case. He (Mr. Courtier-Dutton) did not know if there were any timber merchants present that night, but he thought that if such marvellous virtues could be found in a piece of deck plank, the days of iron shipbuilding were at an end; they should return to the old wooden walls, and the price of timber would go up about 50 per cent. Mr. Bergström appeared to have fallen into another and slighter error. Further down in the next paragraph but one (page 219), he said :—"It will be necessary here to state that while in the well-decker all the erections above the main deck have been considered buoyant, the poop and forecastle only are included in the spare buoyancy percentage of the three-decked vessel, as the bridge has openings in the after end." This was not quite fair, for if Mr. Bergström would again refer to the foot notes to the tables he would find that where a bridge house was open or partially open at the ends, although it might not largely affect the spare buoyancy, still it was not ignored altogether, but was assessed at $\frac{1}{2}$ or $\frac{3}{4}$ of its actual length, and the reason was seen when they remembered the protection afforded by the bridge sides to the engine and boiler openings. If they supposed the vessel to be supported on the crest of a wave, something like that shown in one of the diagrams attached to the paper, it would be observed that the bridge side plating was to a large extent immersed, and so afforded valuable protection to the engine and boiler spaces, even when the bridge was open at the ends.

Mr. G. W. Sivewright said that in the table of comparisons, part 7, paragraph 44, it was shown that the well-deck steamer was trimming $7\frac{1}{2}$ by the head when loaded. He would like to explain that the vessel referred to was one of the first they built of this type and they had simply

added the long bridge on to the ordinary well-decker they were then building. After these calculations were completed, and they had had some experience of the general loading of this vessel, the future designs of the well-deckers were altered so that they would trim on an even keel when completely loaded. He noticed that several of the speakers had drawn comparisons between the spar-deck, three-deck, and well-deck steamer. This paper was not written with the idea of proving the superiority of one vessel over another, but there could be no doubt that the well-deck steamer was more suitable for the trade of the North-East Coast shipowners. These vessels not having an intermediate deck could be loaded quicker, stowed easier, and cost less money to build for the amount of cargo carried. He could only congratulate Mr. Bergström upon the manner in which he had got out his two papers "On the Structural Strength of Cargo Steamers." Papers of this description require a great amount of study and calculation.

Mr. F. YEOMAN took it that no particular favouritism was shown in the paper so far as he could gauge. As a non-technical individual, and, by the way, he might be permitted to say that sometimes he wished naval architects would use, as far as possible, easily understood phrases, instead of the ultra-technical phrases difficult to outsiders. The paper seemed to deal fairly with the three types. He was immensely tickled in reading one paragraph in the paper, on page 221:—"As to the height of platform, which is considered of such vital importance, it cannot be denied the well-decker *has plenty of it*, and no doubt makes her have *a very dry bridge* in ordinary weather *on which to cross the Atlantic*, when compared with the other types." They were not responsible for that in Hartlepool, but it was the opinion of an expert. It had occasionally been rather rich to those who had felt interest in this question to hear of the three-decker and the spar-decker attempting to climb up to the quoted superexcellence of the once much abused well-decker. Especially was this the case when they remembered that not so many years ago a judge at a Board of Trade enquiry doubted whether such vessels ought to be engaged in that trade at all. They had surely gained much valuable information in the interim. It seemed to him, so far as he could gather, that well-deckers were strong in what he considered several vital particulars, such as spare buoyancy and stability. They were low priced—a consideration to the shipowner. The well-decker was also very easily stevedored, an advantage in having to take all kinds of cargo in every part of the world, not from choice but often from compulsion, and last but not least, to every British shipowner worthy of the name, they were, under all these varying conditions, a proved safe type of

ship. A gentleman had said that some wished to spend more money a build a ship that would go all round the world. That seemed rather suggest that the well-decker was not capable of going all round the wor Their experience in Hartlepool proved the contrary. He should like state this in public, that he believed the type of vessel, of which they w lamenting the loss of so many, was built as an escape from the persecuti of the safer type many years ago, say since 1873, by the Board of Tra He could only repeat that of an average of 350 well-deckers since 18 in one insurance association but one steamer had been reported missi whilst of about 600 steamers of the type having more than one deck l no less than ten or eleven were posted as missing in the last year tabulat Shipowners could not afford to overlook this fact, and as marine archite they were bound to aim at doing everything possible towards remedy this disparity in the loss of life at sea.

The VICE-PRESIDENT said it had been suggested that there might other members who would like to speak on this paper, and he should l to take the sense of the meeting as to whether any further discussion this paper should be adjourned, or whether to consider it closed t night.

On the motion of Mr. WEIGHTON, seconded by Mr. FOTHERGILL, discussion was adjourned.

WEIGHT OF MACHINERY IN THE MERCANTILE MARINE.

By WILLIAM BOYD, Past-President.

[Read before the Institution on April 12th, 1890.]

The subject which the writer desires to bring before the Institution is one which has always possessed great interest to all who are concerned in obtaining from any given expenditure of capital the highest possible performance in the propulsion of the steamship.

It has been frequently brought to the notice of the Institution, viz., in Messrs. Marshall and Weighton's paper, read in April, 1886, on "High Speed Engines," in Mr. J. P. Hall's paper, read April, 1887; again notably in a paper by Mr. R. Thompson in November, 1887, on "Cargo Steamers;" and especially in the valuable information supplied by Mr. Macarthy during the discussion that followed on that occasion.

But in all these papers and discussions the particular point of how far it would pay the shipowner to adopt engines of lighter design has never been very specifically dealt with, and the author has felt that perhaps good purpose could be served by some further discussion and elucidation of the matter, especially as he thinks that mistaken and exaggerated views are sometimes held on the subject.

The difficulty of concentrating the various considerations which affect the problem into the space available on an occasion of this kind have been much greater than he ever anticipated, and the present must be regarded only as an attempt to touch the fringe of the subject, and as applying only to one branch of marine engineering practice, leaving out of consideration all special cases where machinery is designed for special purposes.

Another condition should be made clear at the outset. In all the calculations of weight, etc., which follow, the present existing rules for the strength of boilers and engines in the mercantile marine have been

adhered to, and the machinery referred to in the paper is supposed to be designed to pass Lloyd's and Board of Trade rules, and, whether in the lighter or heavier engines, to have the factor of safety provided for in those rules, and also ample wearing surfaces. It is the more necessary to make this clear, seeing that when once a departure is made from some well understood basis of this kind, the door is opened to a variety of other considerations. For example, it is held by many that the factor of safety in use for marine boilers is greatly in excess of what is necessary. Mr. Marshall said in the discussion on Mr. Hall's paper that, in his own practice, when at liberty to do so, "he was reducing the thickness of shell plates 20 per cent.;" and similar modifications of design might be applied to crank-shafts and many other parts of machinery. Then again, in the design of the marine boiler many attempts have been made with more or less success to reduce its weight by alterations involving less dead-weight of water to be carried, such, for example, in what are known as tubulous boilers; and again, by employing boilers of the navy type and other similar designs, to obtain improved results.

This question of the type of boilers opens out several questions of some difficulty. It might reasonably be asked why, if you propose that the shipowner should boldly face the question of increased piston speed, you do not also suggest the possibility of an improved type of boiler of equal evaporative efficiency but carrying less dead-weight of water, and also of less structural weight? The answer is, that in the opinion of the author the present type of marine boilers is specially suited to the various conditions under which its efficiency must be considered. The navy type boiler of reduced diameter occupies less room vertically, this being the direction in which space is of least value, but occupies more room longitudinally, where length is of vital importance and very great value, and the same remarks apply with more or less force to other types and modifications of present practice.

This problem of the space and weight in any given steamship which is devoted to steam producing, as distinct from steam using purposes, deserves an essay on its own account, but the author has been unable to undertake the enquiry on the present occasion. He has therefore thought it best to deal with the present type of boilers (or the steam producing department) as a "constant," and to devote his remarks to modifications in the engine or steam users, and to certain moderate improvements which may be made in the boilers without departing from the present recognised type.

The author therefore has simply taken into consideration the ordinary

marine engine of the present type, with machinery and boilers of the ordinary design, and constructed of materials ordinarily in use, and of ample strength and surface.

Referring to the light engines mentioned further on in the paper, a short specification is given of the modifications contemplated so as to obtain the reduction in weight. It will be seen that these modifications are of a moderate character, the idea being to confine them to changes which may be considered as reasonably applicable to the mercantile marine with a view to continuous economy. By the adoption of special designs, such as light and braced wrought iron columns for carrying the cylinders, and other similar modifications, a greater reduction of weight could of course be made, but it would be at a greatly increased cost, and in the author's opinion the result would not be suitable for the mercantile marine, or be likely to be adopted therein.

The value to the shipowner of a ton saved in the weight of the propelling machinery is the most important element in the following calculations, and the author has been kindly supplied with exact information on this head by Mr. J. D. Milburn and Mr. Macarthy, whose authority on the subject will doubtless be recognised. Mr. Milburn considers the saving per ton in weight per annum to be £7 15s. for vessels employed in the Eastern trade, and £5 15s. in the Black Sea trade. Mr. Macarthy names a rather lower figure, viz., £7 and £5 for the Eastern and Black Sea trades respectively, so that the author has adopted the figure of £6 as being a fair allowance for the present purpose. Both authorities explain that this value per ton saved in weight is only applicable to vessels carrying dead-weight cargoes, and that as in the Eastern trade vessels occasionally carry "measurement" (or partly "measurement") cargoes, this gain should be modified in such cases, and that in the case of some cotton cargoes it would disappear altogether, and that in such cases there would be no advantage at all to be derived from the use of lighter machinery. The author has given this explanation for the purpose of anticipating obvious criticism, but for general trading he believes he is not far off the mark if he values the saving in weight at £6 per ton per annum.

The author has adopted as the basis from which to start his comparison a vessel of the following dimensions:—Length, 310 feet; beam, 40 feet; draught of water, 22 feet; dead-weight, 4,200 tons; speed, 9½ knots, fitted with a set of engines of the following sizes:—Cylinders, 23, 37, 60 by 39 stroke, with two boilers containing 3,900 square feet heating surface, 160 lbs. pressure, and capable of developing under natural draught when

running at 75 revolutions (piston speed 487 feet per minute), 1,300 indicated horse-power, and of driving the vessel (of which particulars are given above) at a speed of 9½ knots on loaded trial trip. The weight of these engines with water in the boilers ready for sea, inclusive of Board of Trade and Lloyd's usual spare gear, will be 256 tons, equal to 442 lbs. per indicated horse-power.

Bearing in mind the explanatory remarks in the former part of this paper, we now proceed to ascertain to what extent and at what cost the total weight of these engines could be reduced so as to add to the cargo carrying capacities of the vessel, while maintaining at the same time to the fullest extent the efficiency of the machinery, and with ample provision against breakdown on a long voyage. The modifications proposed are as follows, and they are shown on Plate XXXIV., and can thus be readily contrasted with the ordinary engine shown on Plate XXXV.

The condenser, instead of forming part of the structure of the engine (as is now usually the case), is a separate vessel composed of brass plates of suitable thickness placed on the port side of the engine room and connected by copper pipes to the air and circulating pumps, which are still attached to the main engines, and are driven by levers in the ordinary way from the piston rod of the intermediate cylinder.

The cylinders are carried on six cast steel columns, resting on and attached to the bed-plate. The bed-plate, as well as the columns, is of much lighter design than is ordinarily employed, and like them is composed of cast steel.

Cast steel is also substituted for cast iron in the following parts :— Cylinder covers and pistons, thrust carriage, plummer blocks, and stern tube.

The air and circulating pumps and feed and bilge pumps, instead of being constructed of cast iron with brass liners in the usual way, are made wholly of gun metal of adequate thickness.

Brass castings throughout are also substituted for the usual practice in the shipside valves, the steam regulator, and in the stop valves and safety valves on the boilers.

It is also proposed that, to reduce the weight as far as possible of the crank or tunnel shafting, a hole about 2½ to 3 inches diameter should be bored through the centre of all this shafting, which can be done without encroaching on their strength.

These shafts, as well as the piston and connecting rods, will continue to be made of scrap iron or scrap steel, as no allowance in the factor of safety is granted by the rules for the employment of ingot steel in these parts of the engines.

The effect of these alterations is to reduce the total weight of the machinery with Lloyd's and Board of Trade spare gear, and with water in the boilers ready for sea from 256 to 240 tons (equal to 413 lbs. per indicated horse-power), being a saving in weight of 16 tons of the annual value of £96 to the shipowner on the scale already given.

The important question now arises as to the cost at which these modifications can be effected. Careful calculations have been made in the author's office, based upon the present difference in the cost of cast iron and cast steel castings, and on the additional cost involved in the removal of the condenser from the main structure of the engines into a separate vessel in the manner described above, and without troubling the Institution with too many details, the author is of opinion that the changes detailed above would involve an extra cost in the selling price of the machinery of £1,500, in return for which there would be (as already shown) a saving in dead-weight of 16 tons, worth to the shipowner £96 per annum, representing an interest on the capital expended of 6·4 per cent. per annum.

It will probably be admitted that this is an inadequate return for capital so expended in a steamship; at any rate, that is the opinion of the author, and his object is now to show that, in more ways than one, and in more than one direction, some part of this capital can be better employed, and also that with sufficient courage on the part of the shipowner to face an increased speed of piston, equal results in the speed of his ship can be secured by a lessened rather than by an increased expenditure of capital.

To bring to bear some actual experience in regard to the question of increased speed of piston, the author has referred to the records of the performances of marine engines when he was engaged in their manufacture twenty-five years ago, and he finds that in the years 1863 to 1869 inclusive, the average piston speed of the screw engines built by his firm (which were mainly of the simple surface condensing type) was 333 feet per minute. In the four years which followed (1870 to 1873 inclusive) the average rose only to 340 feet per minute, and these engines were entirely of the ordinary compound type working on two cranks. In the following ten years, 1875 to 1884 inclusive, the record gives an average piston speed of 424 feet per minute, these being also all compound engines. From 1885 to 1888 inclusive, the average was 494 feet per minute, the engines being mainly triple expansion on three cranks, and in 1889 the average rose to 558 feet per minute, these being, of course, all triple expansion engines. Thus in the twenty-five years

from 1863 to 1888 there is an increase in piston speed of 161 feet per minute, or say 50 per cent., and material progress is being daily made in the same direction.

Increase in piston speed is the greatest and most important factor in the problem of reducing the size and weight of engines, and it is seen that with the introduction of the three crank engines in about 1884, an increase of fully 15 per cent. was obtained over that which was ordinarily in use in the best compound and two crank engines in the ten years from 1875 to 1884. This increase is being gradually and successfully pursued, and the author is of opinion that still further advantage can be taken of this means of reducing weights. Doubtless there is a point at which the increase in piston speed will add to the momentum of the moving parts to such an extent that it would involve a radical alteration in the ordinary design in order to reduce their weights considerably, but this point is not yet reached, nor is it in question in the proposals now submitted to the Institution.

The author feels assured that with the present equally balanced engine, with larger bearing surfaces and efficient mechanical lubrication, the piston speed may safely be increased by 10 or 15 per cent. above what is put down for the normal engines, thus raising the piston speed to 570 feet per minute. He has in his own practice repeatedly made use of such increased piston speed with satisfactory results, and he considers that the ordinary type of engine may be made to develop this increased power with certainty and safety over long voyages without incurring any risk beyond that inseparable from ordinary service at sea.

Mr. Hall-Brown in his recent paper seems to be of opinion that to increase the number of revolutions by 50 per cent. would materially interfere with the efficiency of the propeller, but his objections were well met by Mr. Patterson in the discussion which followed, and the author can only add that the revolutions given by Mr. Hall-Brown as producing a propeller efficiency which, in his opinion, is incapable of improvement, are only 65 for a stroke of 39 inches, or 422 feet per minute, which has been shown above, was the practice of ten years ago, with two crank compound engines. The author has obtained excellent results with propeller running at 75 to 80 revolutions in engines with 39 inches stroke, and he is of opinion that this could be increased, say 20 to 25 per cent. (say 90 to 95 revolutions), without any material interference with propeller efficiency if suitable provisions are made in its design.

He would also point out that the experiments on which Mr. Hall-Brown bases his arguments as to propeller efficiency are merely model

experiments in a tank, and with a very high number of revolutions, and cannot therefore be taken as absolutely conclusive in reference to ordinary working at sea, but the author also desires to add that the object of his paper principally being to discuss the weight of the machinery in an ordinary screw engine, he puts on one side as much as possible the discussion of all collateral questions which would only indirectly affect the main points under consideration.

It will be seen above that the power developed by the normal engines, supplied with steam from boilers of normal size (3,900 square feet heating surface), will be 1,300 indicated horse-power, while running at 75 revolutions, giving a piston speed of 487 feet per minute.

As argued above, the author considers that this piston speed might be increased to 570 or 580 without risk or objectionable wear and tear, provided means were adopted for a larger supply of steam adequate for the increased power developed.

This additional supply of steam can be obtained in two ways:—First, by increasing the size of the boilers, or, second, by adding to their efficiency by the employment of forced draught.

If a piston speed of 585 feet per minute (or say 90 revolutions) were adopted, the power then developed by the cylinders named above would be 1,550 indicated horse-power, and the problem would work out thus:—

The boilers to supply steam for 1,550 indicated horse-power must be increased in size so as to contain 4,650 square feet, and in weight by 12 tons. The weight of the additional water contained in the larger boilers will be about 7 tons, and allowing also for some slight additional weight to the machinery, so as to provide for extra wearing surface and extra strength in certain parts, the total weight of the machinery would be increased above that of the normal engines by say 20 tons. The cost of this addition may be reckoned as £400.

What is the position of the shipowner under these modifications?

1. His engines develop 1,550 indicated horse-power as against 1,300 indicated horse-power. The difference in power representing a difference in speed of say three-quarters of a knot on loaded trial trip.
2. Per contra:—
   (*a*) He would lose 20 tons in the carrying capacity of the ship, representing an annual loss of £120.
   (*b*) And he would burn 4 tons per day more coal, representing an annual additional expenditure of say £880, on the supposition that the vessel was actually steaming 220 days out of 365, and that the coal cost £1 per ton.

(c) The cost of increasing the size of the boilers, etc., would be £400, the interest of which, at 10 per cent. per annum, represents an annual charge of £40?

How far does this gain of three-quarters of a knot in speed balance the loss of carrying capacity and extra coal consumption, and interest on capital expended, amounting together to £1,040?

The second alternative is to increase the efficiency of the boilers by the addition of forced draught.

This proposition opens up many vexed questions hardly germane to the points immediately under consideration, and the author does not propose to discuss in any degree the success or otherwise of the various systems in use at the present day, or to enter into any description of them. He has based the following calculations on the employment of a moderate arrangement of "assisted" draught on the closed ashpit system, which he has himself fitted into 22 steamers, with uniform success.

Retaining a piston speed of 585 per minute (say 90 revolutions), an indicated power of 1,550, and a speed of ship of 10¼ knots, a supply of steam could be easily supplied from boilers of less size than those proposed for the normal engines. The experience of the author would show that boilers containing 3,700 square feet heating surface would be ample to accomplish this, supposing them to be fitted with assisted draught, giving a pressure of ·4 to ·5 inch of water under the bars, and about ·2 inch above them.

The net cost of this alteration may be taken as £280, that is, after giving credit for reduction in size of boilers.

What is now the position of the shipowner?

1. He gains three-quarters of a knot in speed as above.
2. Per contra:—
   (a) The additional weight of fan and engine, and increased wearing surface would be almost exactly compensated by the reduced size of boilers and less amount of water carried in them, thus leaving the dead-weight of machinery practically the same as in the normal engines.
   (b) As to consumption of fuel. We might argue from several instances that owing to the increased furnace efficiency and the perfect control at all times, and under all conditions, over the rate of steam production, even with inferior coal, the consumption per indicated horse-power would be lessened sufficiently to provide for the

extra coal required to produce the additional indicated horse-power, but as this argument might introduce debateable questions foreign to this paper, we will assume that the consumption per indicated horse-power remains the same. Therefore, we will assume that the additional coal burned in twenty-four hours will be the same as if the additional indicated horse-power had been obtained by using larger boilers, and will be represented by £880 per annum, as above.

(*c*) The annual interest on the expenditure at 10 per cent. will be £28.

Thus in the case of forced draught, against the gain of three-quarters of a knot in speed, the owner has to set a debit amounting to £908, as against £1,040 by adding to the size of boilers, being a balance in favour of the forced draught system of £132. Probably much might be said by way of enlarging the further comparison between these two systems for procuring increased power out of any given set of engines, but that is not the immediate object of this paper, and is therefore passed over.

The real value of this three-quarters of a knot to the shipowner is difficult for anyone but a shipowner to assess, but from Mr. Macarthy's statements in his speech on Mr. R. Thompson's paper, each day saved on the voyage would seem to be worth, for reduced cost in working the ship, about £15 per day. The increase of speed on a voyage to Bombay and back would mean a saving of four and a half days on the double voyage, and assuming the vessel made four such voyages in the year, this would give a result of eighteen days saved at £15 per day = £270.

The author hopes that some members of the Institute who are conversant with this branch of the subject will say how far such a result would compensate for an increased capital expenditure and increased coal consumption, indicated above, in the case of larger boilers and assisted draught respectively.

Pursuing this enquiry in an opposite direction we will now work backwards from the normal engine, and suppose that the shipowner is content with a speed of 9½ knots on loaded trial trip, which may be taken to represent an average of 9 knots at sea, and that while willing to face a higher piston speed he prefers to employ this means of maintaining the same indicated horse-power, and thus at the same time reduce his capital expenditure as far as possible.

Assuming a piston speed of 570 feet per minute, engines having

cylinders 21, 34, 55 by 36 stroke, when running at 95 revolutions, would, if sufficiently supplied with steam, develop the same power as the normal engine, viz., 1,300 indicated horse-power, and drive the vessel at a speed of 9½ knots on loaded trial trip.

Allowing the boilers to be of the same efficiency they must be of the same size as those for the normal engines, and contain, say, 3,900 square feet of heating surface, and the author estimates that machinery of this kind could be fitted at a reduction in cost to the shipowner of £1,400 on the normal engines.

The weight of these smaller engines supplied with steam from boilers of extra large size (3,900 square feet) will be 218 tons (equal to 375 lbs. per indicated horse-power), and it will thus be seen that a saving in weight is effected of 38 tons, which is very considerable and important. In addition, therefore, to the saving of £1,400 in first expenditure of capital, there must be added a saving in weight of 38 tons, worth, on the scale hitherto employed, £228 per annum.

Pursuing the same comparison—but adopting a system of assisted draught to increase the efficiency of the boilers instead of adding to their size—we find that boilers containing 3,100 square feet of surface would be ample for the purpose with the ashpit and other pressures already named, viz., ·4 inches of water below, and ·2 inches water pressure above the firebars. The cost of this installation would be about the same as that of engines having the same sizes of cylinders (viz., 21, 34, 55 by 36), but with large boilers (3,900 square feet), so that the consideration of capital expenditure remains the same in each case. But the total weight would then only amount to 203 tons (equal to 350 lbs. per indicated horse-power), representing a saving in weight over the normal engines of 53 tons, representing a saving (at £6 per ton per annum) of £318 per annum.

Thus, the smaller engines running at 95 revolutions, with a piston speed of 570 feet per minute, can thus be made available either by fitting larger boilers working under natural draught; in which case there is a saving in capital expenditure of £1,400, and in dead-weight of machinery of 38 tons, or by fitting smaller boilers worked with assisted draught, in which case the saving in capital expenditure would remain about the same, but there would be a saving of weight of 53 tons as against 38 tons in the former case.

The author wishes to sum up his conclusions briefly as follows :—

There are three alternatives open to the shipowner, whereby he may adopt improvements in the propelling machinery.

1. He may retain a moderate rate of piston speed, and by an expenditure of capital of £1,500 add to the carrying capacity of his vessel by 16 tons.

But if he can admit the possibility of increased piston speed (be it well understood with increased wearing surface and strength of certain parts to correspond therewith, and as already explained constructed in accordance with the present Board of Trade and Lloyd's rules), he can adopt two other alternatives.

2. He can add to the speed of his ship by three-quarters of a knot, by the adoption of increased size of boilers, or by adding to their efficiency by the employment of assisted draught.

3. Or he can retain his normal speed of 9½ knots, and save capital, expenditure, and weight to the extent and in the ways already described.

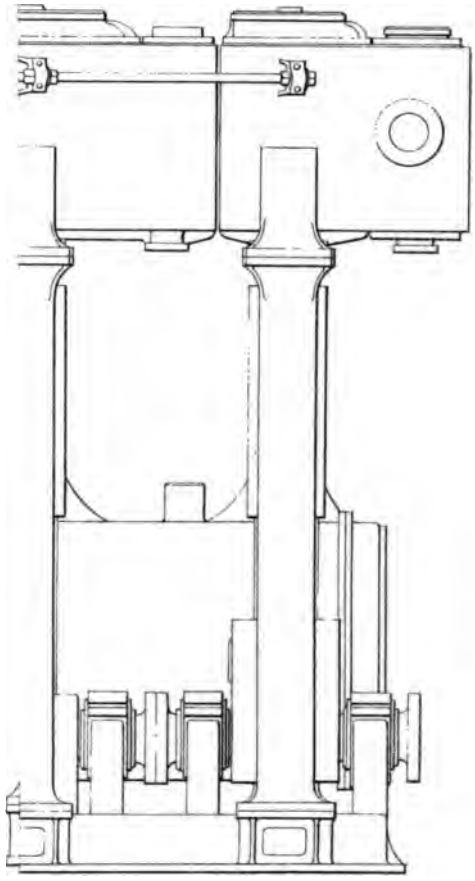
The author feels that proposals of this kind must be open to much friendly criticism, but the calculations he has made have been fairly and honestly prepared to the best of his ability, and in a great measure based upon his own experience.

At any rate it is an honest attempt to throw additional light upon some of the problems which must be in the minds of all who desire to add to the efficiency of the marine engine, and without pretending to say that this is the best or only direction in which such efforts can be turned, still he ventures to think that this is certainly one line into which the members of this Institution might with advantage turn their attention.

In conclusion, the writer desires to acknowledge the valuable assistance he has received from Mr. L. Rusden, the manager of the engineering department of the Wallsend Slipway, in the preparation of this paper.

System of Draught.	Design of Engine	Cylinders.		Boilers. Heating Surface. Square Feet.	Revs. per Min.	Piston Speed. Feet per Min.	I.H.P.	Weight.		Speed of Ship. Knots per Hour.	Cost.	
		Diameters	Stroke.					Tons.	Lbs. per I.H.P.		More than Basis.	Less than Basis.
											£	£
Forced.	Normal.	21″, 34″, 55″	36″	3,100	95	570	1,300	203	350	9½	...	1,400
Natural.	"	"	"	3,900	95	570	1,300	218	375	9½	...	1,400
"	"	23″, 37″, 60″	39″	3,900	75	487	1,300	256	442	9½	Basis.	Basis.
"	Light.	"	"	3,900	75	487	1,300	240	413	9½	1,500	...
"	Normal.	"	"	4,650	90	585	1,550	276	400	10¼	400	...
Forced.	"	"	"	3,700	90	585	1,550	256	370	10¼	280	...

ercantile Marine."



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NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

SIXTH SESSION, 1889–90.

PROCEEDINGS.

CLOSING BUSINESS MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON MONDAY EVENING, MAY 12TH, 1890.

F. C. MARSHALL, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the last General Meeting held in West Hartlepool, on April 12th, which were approved by the members present, and signed by the President.

The discussion on Mr. G. Bergström's paper "On the Structural Strength, etc., of Cargo Steamers of Different Types" was resumed.

The discussion on Mr. W. Boyd's paper on the "Weight of Machinery in the Mercantile Marine" was then proceeded with.

This was followed by the Closing Business of the session.

"ON THE STRUCTURAL STRENGTH, ETC., OF CARGO STEAMERS OF DIFFERENT TYPES."

ADJOURNED DISCUSSION.

Mr. W. HÖK, in resuming the discussion, said Mr. Bergstrôm had given them a comparison of the longitudinal strength of three distinct types of modern steamers: the well-decker, the three-decker, and the spar-decker. He had for that purpose assumed the three steamers of same length, same breadth, and same carrying capacity; and his calculations furnished him with the result—that the well-decker was longitudinally the strongest ship, then the three-decker, and then the spar-decker. These results were not strange, considering the way in which they had been obtained. He did not doubt for one moment the correctness of Mr. Bergstrôm's figures; but he submitted that the result was due to the way, and, in his opinion, to the mistaken way, in which these ships had been compared. Taking minor points first, they noticed that the three-decker and the spar-decker had only one iron deck each, the upper deck in both cases, and that their respective main decks were of wood, whereas the well-decker, by virtue of its bridge being included in the strength calculation, had two iron decks. He submitted that the three-decker and the spar-decker had in this way been unfairly treated, both as regarded carrying capacity and longitudinal strength, especially as the matter of laying an iron main deck instead of a wooden one in no way violated the rules of Lloyd's society. It would then have been found that the stresses that came upon the material in the three-decker and the spar-decker would not compare very unfavourably with those falling upon the well-decker. Or, if they liked, compare Mr. Bergstrôm's three-decker and spar-decker with a well-decker with a short bridge, so short that it cannot legitimately be included in the calculation for the longitudinal strength; and again the ensuing result would be more in favour of the former ships. Regarding the real position of the well-decker compared with the other ships, he did not for one moment hesitate to express his conviction, or rather to express the fact, that compared with ships with continuous decks, the raised quarter-deck steamer was highly deficient in longitudinal strength. The reason for this is easy to find. It lies in the break of the raised quarter-deck ship, which, as was well known, was its weak point. He submitted that as long as this weak point existed it would be absolutely wrong, and not until the break by the employment of superior and altogether different modes of strengthening had been made equal in resisting power to a deck of unbroken continuity would it be right, to com-

pare the longitudinal strength of well-decked steamers with other steamers by the method nowadays in vogue. He did not forget that the well-decker had been greatly improved and the break recently strengthened in a considerable degree, but for all that he believed he was right in saying that with the present mode of strengthening, one was hardly capable of making the break as strong as if the deck had been continuous. Suppose that the break could not resist the strains without deflecting, the consequence was that a portion of the strains that should have been taken by the deck plating was transferred to the sides and the bottom plating, the real amount of that portion depending on the resisting power of the break. To his mind a raised quarter-deck steamer with a weak break was about equal in strength to a steamer without any iron deck at all, and a well-decker with a modern break of superior strength and rigidity, to a steamer covered with a continuous deck of ¼ inch to ⅜ inch plating. These were his reasons for saying that they did not get a correct idea of the relative longitudinal strength of raised quarter-deck and flush-decked steamers by the ordinary method for calculating longitudinal strength, and that a comparison between these types is misleading until the absolute strength of the break is ascertained when first a due appreciation of the stresses on the deck plating, sides and bottom plating was made possible. Having rid himself of the raised quarter-deck steamer, he submitted that, in order to obtain the relative longitudinal strength of other types, the relation between depth and length should be the same for all. A steamer of small depth would always compare unfavourably with a steamer of great depth, both as regards strength and weight; therefore when the longitudinal strength of steamers was compared, the fixed quantities should be length, depth, and breadth. If such a comparison was made he believed they would find that the spar-decked ship was longitudinally stronger than the three-decked, the reason for this being nothing else but that the material added in converting the former type into the latter was not of sufficient amount to secure equal longitudinal strength to these two types when loaded to their respective freeboards, especially as the freeboards were influenced by the amount of erection in the second type and not in the first. In comparing whether one type could be constructed lighter than another type, he believed the figure giving the truest indication thereof was the percentage of steel used per ton of load displacement. People were apt to forget that the material used in the construction did not only carry the cargo, but also the wood, fittings, propelling machinery, etc.; therefore, in order to obviate the necessity of knowing the weights of these items, the truest and simplest way of comparing weights was the percentage of

net or invoiced steel to the load displacement. Moreover, if they compared ships of different types but of the same ratio between length and depth, not forgetting, however, that the true depth was the depth to the upper deck increased in raised quarter-decked steamers and three-decked steamers with an amount equivalent to the influence of their respective erections on freeboard, they would find there was little to choose between the different types. But, generally speaking, he believed that if the spar-decked ship was fitted with any substantial erections she would come out heavier than the three-decked ship, and that the raised quarter-decked ship, if she was not highly favoured, both as regards the value of her erections in fixing her load-line and as regards the small amount of longitudinal strength required in that type, would be heavier than either of them. However, one thing was plain, that comparisons of weight as well as of strength between different types depended altogether on how they selected the relative proportions of the ships they compared. He would just by an example show the influence of length on ships. Assume a ship of a certain length and given transverse dimensions:—

Call weight of steel $= W$.
Load displacement $= D$.
Tons per inch immersion $= T$.
Length of ship $= L$.
Increase of draught in inches per 10 feet decrease in length $= n$.
Now shorten the ship and make her length $= L_1$.

For the sake of simplicity he assumed that the weight varied as $L \sqrt[3]{L}$, then weight of shortened ship $= W \times \frac{L^1}{L} \sqrt[3]{\frac{L_1}{L}}$, and displacement of shortened ship $= D \times \frac{L_1}{L} + \frac{L-L_1}{10} \times n \times T \times \frac{L_1}{L}$ and $\frac{\text{weight}}{\text{displacement}}$ of shortened ship $=$

$$\frac{W \times \sqrt[3]{\frac{L_1}{L}}}{D + \frac{L-L_1}{10} \times n \times T.}$$

Make $D = 10{,}000$ tons.
„ $W = 2{,}000$ „
„ $L = 400$ feet.
„ $T = 40$ tons.
„ $n = 1{\cdot}6$ inches.

Shorten the ship say 70 feet $= L - L_1$, and $\frac{\text{weight}}{\text{displacement}}$ of shortened ship (330 feet) $=$

$$\frac{2{,}000 \times \sqrt[3]{\frac{330}{400}}}{10{,}000 + \frac{70}{10} \times 1{\cdot}6 \times 40} = 18 \text{ per cent.}$$

Thus by making the ship 17·5 per cent. shorter he had reduced the weight of steel per ton of displacement from 20 per cent. to 18 per cent.; and as the value of steel to total displacement for most cargo steamers built on this coast lies between these two limits, it proved that by selecting their proportions favourably, they could get any steamer or type to be lighter or heavier than another according to their requirements and the purpose they had in view. He therefore believed there was very little in the weight to choose between the different types; but as there were any amount of spar-decked and raised quarter-deck steamers built, and only few three-decked ones, there must exist other and more important reasons that induced the shipowner to choose the former types. As he could not possibly mention any of those reasons without following Mr. Bergstrôm into the domain of stability, freeboard, reserve bouyancy, cubic capacity, etc., and as his remarks had almost taken up the allotted time, he must abstain from discussing the relative merits of the different types in other respects than in longitudinal strength, although such an one-sided comparison must necessarily be very incomplete, as the other considerations which guided the shipowner were of altogether greater importance; in fact of such importance that the matter of more or less strength was, he believed, in the minds of most owners, not at all considered; and for that argument he had no stronger proof than the apparently great liking for the weak and favoured raised quarter-deck steamer, which so many shipowners seemed to entertain. Finally, although he could not agree with Mr. Bergstrôm in some of his conclusions, he fully appreciated the amount of work involved in preparing his paper; and believed that this Institution should consider themselves fortunate in having in Mr. Bergstrôm a member who, in his own spare time, for the love of science and his profession goes through that unlimited amount of work involved in the preparation of such a paper as that which they were now discussing.

Mr. H. Macoll said the paper had been discussed from a variety of standpoints, and with a very considerable variety of opinion. They had had arguments for and against the present style of well-deck ships; but the fact was that ships of all classes nowadays were borrowing the best qualities one from the other, and it was difficult now to tell what was the typical well-deck ship and what the spar-deck; and the flush-deck vessels, which a great many people were anxious to have, were gradually being improved out of existence by the addition of structures, such as bridge, poop, and forecastle. They were told by the advocates of these flush-deck ships how very much better they would be if these erections were

made larger and stronger. Well, that was all very well, but if they started from a fair type of the well-deck ship, let them have a fair type of the spar-deck and three-deck ship, then, he thought, the comparison would stand upon much more equal terms than at present. He thought undue advantage had been given both to the spar-deck and three-deck vessel in the paper. That being so, he did not think the comparison exactly fair, and he took rather a different view from the last speaker. His experience in vessels was not very extensive certainly, but as far as it had gone he had kept his eyes open, and observed that some flush-deck ships seemed to strain more and damage their boats and erections much more than the well-deck ships. An awning-decked ship, he knew, of very fair proportions—about 290 feet in length by 40 feet in breadth, and something like 20 feet to the main deck—had carried away her boats several times to his knowledge. A well-deck ship, of practically the same proportions, had never yet damaged her boats after running several years. Now, such facts were difficult to get over, and the well-deckers carried their cargoes and people on board with greater safety than any other type. Therefore, unless they had some valuable points, that could not be the case. Of course, if they exaggerated the matter, and went into very large vessels, he did not know, and would not prophesy, what would occur; but to his mind, the present style of well-deck ships, when properly designed and constructed, were good still for most general cargo purposes. It could not be forgotten that the greater proportion of the carrying trade in their own and other countries was dead-weight. In the command, therefore, of many harbours light draught was a consideration, and for dead-weight and light draught nothing could surpass or equal the well-deck steamer. One matter which demanded consideration was that the improved well-decker was partaking in some of the faults of the flush-deck ship, having so large an extent of the vessel double-decked. In the case of shifting cargo, that was rather a dangerous property, as cargo was never so well stowed in double decks. Of course, stevedores could, and did, stow ships exceedingly well, but they did not always do it. Sometimes they would tell that wherever there was a space below deck wanting filling up they stuck a bit of coal or cargo the exact size of the space into it. That was all very good when this was done, but when they had a vessel with cargo indifferently stowed between decks, and the vessel listed or rolled heavily, all the advantage they got of larger range of stability due to the erections was more than counterbalanced by the tilting of the cargo and the centre of gravity of a shifting cargo going more rapidly to leeward than the length of the

[illegible] and the [illegible] was further exaggerated by the [illegible] of the [illegible] of the rail. Then, when a vessel [illegible] any [illegible] more or less as her beam could it was a [illegible] matter [illegible] the [illegible] with double decks. The ordinary well-deck had very little [illegible] over the upper decks in shipping and [illegible] and in [illegible] the [illegible] and the cargo had the full [illegible] of the vessel [illegible] down: the [illegible] of these advantages was [illegible] the number and extent of [illegible] decks fitted. Another [illegible] which might be referred to was the equipped weights of the vessels as given in the paper. He could scarcely credit that, and had a strong belief that vessels of the dimensions and proportions given could not be constructed in accordance with the present classification rules on the weights given. It might be possible, but he could not see it. One thing might be used—the double bottom did not extend very far across the bottom—that feature was common to all three types. He thought they would be very much better, in view of taking ground, if the double bottom was carried out further towards the sides. This would increase the weight considerably, and make the vessel safer. As to the spar-deck vessel, with greater erections it must not be forgotten they got very little consideration in the freeboard, for the erections were independent of freeboard. If they did obtain any advantage in freeboard, it must be by greater strength, and necessarily greater weight in the structure—they must increase the scantlings to pass at Lloyd's. He thought Mr. Bergström had given them a very useful and interesting paper, and he thanked him for the very valuable information it contained, and he hoped it would not be the last of such papers.

Mr Geo. N. Arnison, Jun., observed that the position he occupied as regards the questions as to whether the well-decker had been too favourably, or as to whether it had been unfavourably, compared in Mr. Bergström's paper, was about midway. It seemed to him that there was evidence of an impartial consideration of the three types of vessels. He could not, therefore, agree entirely with either of the preceding speakers, except in the recognition of the large amount of time and labour expended in preparing the paper. Such contributions to the Institution's proceedings were very laborious to compile, involving as they did elaborate calculations, and thus the question of the structural strength of vessels was a subject not frequently chosen for consideration. He (Mr. Arnison) was not aware that there had ever previously been three typical steamers compared in the manner that they had been in Mr. Bergström's paper. The writer had not, however, contented him-

self with considering the question of "strength," he had also gone into the question of "stability," and by amalgamating the two subjects together, added considerably to the interest of the paper. Mr. Bergström appeared to be excessively modest when he spoke of it as being "incomplete," although, no doubt, as he suggested, there is sufficient scope for a further contribution on the "strength of vessels." Seeing that Mr. Bergström's paper was the outcome of steady application, and that, doubtless, every care had been taken in seeing that the calculations were accurate, there was, after all, not much scope for discussion. Previous speakers at West Hartlepool, and Mr. Hök that evening had, however, endeavoured to show that the "well-decker" had had an unfair advantage as compared with the "three-decker" and "spar-decker." He (Mr. Arnison) was not inclined to agree with these views; on the contrary, it appeared to him that the comparisons were, on the whole, fairly impartial. In several passages in the paper it is evident there is no bias in favour of the "well-decker" or against the other typical vessels, *e.g.*—"As regards the density of homogeneous cargo, the writer is of the opinion that a better ship than the spar-deck type could hardly be designed, as her density, being the medium between the other two types, enables her to fill the holds with cargoes which would not immerse the three-decker to the same draught of water, *while the well-decker* in carrying *the same cargo as the spar-decker* would also carry a considerable amount of empty space. The disadvantage in either case is evident." Again, "There is no doubt that three-deck vessels are afloat with very little stability, and probably this want of righting power and range of stability have been the cause of the loss of some of this class of steamers. But it will not do to condemn the type on this point before knowing the reasons why, and this want of stability could easily be traced to deficiency of beam in those three-deckers. *The present comparison is a sufficient proof that a three-deck steamer can be built with a fair amount of stability* if of reasonable proportions to suit the design." Again, "*The last items in the table are the trims of the vessels when loaded homogeneously.* There is nothing remarkable about them except that, supposing the trims of the well-decker to be the actual trims, the spar-decker *exhibits less tendency for trimming by the head than the other types*, notably the well-decker." Other instances could be quoted, but these will suffice to show that there is no special pleading for the "well-decker." Objection had been taken that Mr. Bergström in comparing the three typical vessels had fixed on the length, beam, and dead-weight capability in each instance. In such comparisons it was

essential that there should be some basis, and there was certainly something to be said in favour of having more than the "dead-weight capability" constant. The objection scarcely seemed to be a serious ground for complaint; at all events, if any members thought that the well-decker had been unfairly favoured, he (Mr. Arnison) would suggest that they undertake other comparisons and contribute a paper similar to Mr. Bergstrom's in proof of the allegation. Thereby the interest in the subject would be increased as well as a valuable addition be made to the Institution's proceedings. It is, however, much easier to criticise than to prepare papers of this class. Again, it had been objected that Mr. Bergstrom had unfairly limited the deck erections in the typical "three-decker" and "spar-decker." Now, rarely, if ever, were hurricane houses in these classes of vessels half the length of the vessel, and without they were, and efficient arrangements made whereby the additional sectional area was not suddenly stopped, it could scarcely be alleged that they added to the structural strength of the hull. Further, it was customary to fit sail ports through the hurricane house sides of such vessels to avoid sides being placed on the promenade deck, and he (Mr. Arnison) was not aware that it was the general practice to fit effective compensation for the loss of sectional area due to the cutting of these openings in the plating. In fact, it might be broadly stated that in three-decked and spar-decked vessels the hurricane houses added little or nothing to the longitudinal strength of the structures. Other points worthy of consideration were indicated by the paper, and it might be interesting to briefly review the comparison of the strength of the three classes of vessels as shown by Mr. Bergstrom's calculations. Certainly it must be admitted the results given were very favourable to the well-deck type of vessel. Taking the figures as to the maximum tensile strain when the vessels are on a wave crest, with bunkers full, viz.:—

Well-deck	4·22 tons per square inch.
Three-deck	5·03 " "
Spar-deck	5·31 " "

It would thus appear the first mentioned is nearly 20 per cent. stronger than the three-decker, and over 25 per cent. in excess of the spar-decked vessel. The corresponding comparison of the sagging strains is not so favourable to the well-decker, in which instance the maximum compression in that vessel slightly exceeds that in the other vessels, but inasmuch as the greatest strain due to sagging only reaches 4 tons per square inch in any of the vessels, whereas the tensile strain due to

hogging runs as high as 6·18 tons per square inch, it is evident that it is more probable the latter strains will be most likely to produce a permanent result. Indeed, in these vessels the sagging strains might almost be dropped out of view, the hogging being taken as the crucial comparative test. If this be so, it appears the well-deck vessel had nearly 20 per cent. less strain per square inch of sectional area than the three-decker with bunkers full, and about 13 per cent. less strain with bunkers empty, the corresponding figures compared with the spar-deck vessel being slightly above 25 and 16 per cent. In considering these figures, which on first consideration might appear to overstate the strength of the well-deck vessel, it must be remembered that the bridge or hurricane house was carried forward to the foremast, and obviated the objection of the sudden break amidships at the forward end of the bridge of the older type of well-decker. He (Mr. Arnison) was, however, in perfect agreement with Mr. Macoll in pronouncing against such abnormally extended bridges, so far as regards the vessel's seaworthiness. As regards the break at the after end of the bridge, owing to its less extent of depth with the raised quarter-deck arrangement, there never had been so much difficulty experienced as at the forward end as to the continuity of the structure. In considering the results of Mr. Bergström's calculations, he (Mr. Arnison) had had brought forcibly to his mind that it was evident that seagoing vessels were at present being constructed much stronger than was customary twenty years ago. In a paper read by Mr. John, then of Lloyd's Register, in 1874, it appeared that a steamer of 3,000 tons had as high a tensile strain due to hogging as 8 tons per square inch. In Mr. Bergström's paper a vessel of 5,000 tons displacement as at present constructed has only 6 tons per square inch. Twenty years ago iron was, however, the material employed, and it had a breaking strain of about 16 to 20 tons per square inch. Now, steel had displaced iron, and its tensile breaking strain was from 28 to 32 tons per square inch. Thus the factor of safety had increased from 2 and 2½ to at least 4 to 5. This was a very great difference and an important step. The improvement was not, however, altogether due to the use of steel. A better distribution of material had had largely to do with this progress. Twenty years ago iron or steel decks for structural strength were not adopted to any extent, but since then the classification rules of Lloyd's Register had been considerably altered in this and similar details. Such papers as that under consideration were of material importance in leading to a proper distribution of material, and they should feel under a debt of gratitude to Mr. Bergström for having prepared it.

Mr. Robert Thompson, being invited from the Chair, said he had not come prepared to make any remarks upon the paper. It was a valuable one for discussion, and in a question of three types of vessels such a discussion might be very much extended. They had built vessels of the long raised quarter-deck type, and also on the three-deck, flush-deck, and spar-deck rule, and it was, as Mr. Macoll said, a remarkable fact, that shipowners always seemed to come back to the long raised quarter-deck ship; and he had no doubt, from their own experience, that the long raised quarter-deck ship, as now built, was quite strong enough for all practical purposes. Some time ago there had been cases of slight local weakness in such ships, loaded with heavy dead-weight cargoes, these vessels falling in with very bad weather. What surprised him was the very small amount of strength added, and from that time to this there had been no further complaints of that type of ship, which showed that, as far as strength went, they had been well built, and that the amount of material in them was sufficient for the work they had to do. When they went into types of ships there were differences of opinion about trimming the cargo, and that, he found, was why well-deck ships were designed in preference to others. People were, however, copying the good points of one and adding them to the other. In point of strength, he thought the three-deck ships, built with the improvements of the well-deckers, substituting steel for wood decks, would be stronger than the long raised quarter-deck ship. He thought the well-deck ship and the three-deck ship, as shown in the paper read, had all the erections they should have as built at the present time, but the erections of the spar-deck ship were very limited. He rather questioned the correctness of some of the figures with respect to the freeboard. He thought in two of these types it should be reduced, the long raised quarter-deck ship was about right. A ship of 290 feet by 38 feet, 22 feet 3½ inches depth moulded, 1,375 tons, he thought certainly a very light weight, and, so far as comparing with his own experience, he did not think they could do it. If they reduced the dimensions of the three-deck ship and the spar-deck ship to give the same dead-weight as the quarter-deck ship, that is with reduced freeboards for the two first-named types, as mentioned above, and added the weight which, in his opinion, ought to be added to the well-deck ship, then they would have a comparison very much alike as far as the strength went, and it would alter the figures, showing the various strains and strengths and their proportionate relations. Papers like this, however, were what they wanted, and he would like to see their thorough discussion on the facts and figures before them. He was sorry his own time had

been so much taken up that he had not been able to go into it as fully as he might have done, but, in his opinion, the Institution wanted papers like this one by Mr. Bergstrôm, and he hoped it would give rise to others of the same description.

The PRESIDENT—Mr. Thompson had complained that these papers had not the full discussion they ought to have; perhaps some gentleman would endorse that opinion by speaking more fully ?

Mr. THOMPSON—I ought, perhaps, to qualify that by saying, discussion bearing more upon detail and calculation, rather than generalisations upon the different types.

The PRESIDENT—I quite understood that. He would now call upon Mr. Bergstrôm to reply.

Mr. BERGSTRÔM said it would be rather difficult to take up all the different opinions expressed upon the contents of his paper, but it seemed to him if he replied to the remarks made at the opening of the discussion by Mr. Trewent, he would, in a general way, reply to most of what was said by other critics. Mr. Trewent expressed surprise that the three-deck and spar-deck vessels had not been put forward by the writer as the superior vessels; and doubtless, it is a matter of surprise, not only to Mr. Trewent, but also to the advocates of these types to find that the so much abused well-decker can hold its own, in fact in many points excels, in the comparisons made. Mr. Trewent went on to say that in his opinion the only constant should be the dead-weight carried, and all other factors made to suit. But, he thought, under such conditions it would not be a comparison at all, and was certain that most of the shipbuilders present would agree with the speaker in saying that unless three out of the four main items, namely, length, beam, depth, and carrying capacity were taken as constant, a comparison of this kind was of little or no value.

Why a type such as the well-deck could not go all round the world he failed to see; ships of the other types were more expensive to build, but it was evident that the extra cost in building the spar-deck or three-deck type did not tend to make them stabler, more seaworthy, or even stronger than the well-decker, and thus the type was no guarantee in that respect. This was further demonstrated by the remarks made by Mr. Yeoman. As regarded the stability of the three-deck vessel Mr. Trewent had seemingly only glanced over that part of the paper, as it was clearly pointed out and demonstrated not only what the stability was in the vessel, with the present erections, but also what it would have been if the

bridge had been closed at both ends. That the bridge in the spar-deck steamer was only taken as 20 ft., he could only say he did not see any reason for making it longer, thereby adding weight and expense to no purpose. Besides the comparison would have been valueless, for a spar-deck steamer with erections was no longer a flush-deck steamer, as the name implied, and as the object of the paper was to compare the well-deck, three-deck, and spar or flush-deck types—he did not think any other kind of flush-deck steamers were built nowadays—the well-decker was simply converted into a three and spar-deck steamer respectively, bearing in mind they had to carry the same dead-weight and to be built as cheap as possible. Mr. Trewent was quite right in assuming that the bridge in the three-decker had not been taken into account in the strains given in the table. It had not, however, been his intent to ignore it entirely, and had not Mr. Arnison, in a very lucid manner, called attention to this objection, he (Mr. Bergstrôm) would have done so in his reply. He was very pleased to hear that Mr. Trewent had taken the trouble to investigate the matter, though he could not quite agree with his results, as he (Mr. Trewent) said, had the bridge been taken in the strains would be reduced something like 20 per cent.: about 10 per cent. would have been more like the thing, seeing the bridge deck was severed nearly its whole length by the casing passing up through it. He would have liked to have said something more on this point, but seeing there was another paper to be discussed that evening, he would pass over to some of the remarks of other critics. But before doing so, he would thank Mr. Trewent for the interest he had taken in the paper.

He really did not know how to suitably answer the criticism of Mr. Courtier-Dutton. Mr. Courtier-Dutton seemed to have mixed up the main and upper decks, and he would like to ask him what the thickness of the the main deck in a three or spar-deck vessel has to do with the stability? If he had looked more closely into the matter he would have found what was said in the paper about the freeboards was quite correct. He was quite amused when he heard Mr. Courtier-Dutton say, if Mr. Bergstrôm had looked more carefully into the tables, etc., as it seemed that it was Mr. Courtier-Dutton who needed to look into those tables more carefully, as the freeboard of a three or spar-deck vessel is not measured from the main deck, which was the deck referred to in the paper. The wooden main deck in the three and spar-decker had been a great boon to some of the speakers, as without it, he was afraid, the discussion would have been rather limited. He was very much surprised to find so many of the speakers losing sight of the plain fact that the paper was a com-

parison of the three types under the conditions set forth at the commencement of the paper. There is a possibility that had the dimensions and carrying capacity been smaller or larger the comparison between the three types might have turned out very different. If he was not very much mistaken, Lloyd's allowed a reduction in the freeboard when two iron or steel decks were fitted, provided there is only one required by the rules, and had he taken the main deck in the three and spar-deck vessels to be of steel, and supposing 2 inches had been granted in the freeboards, he would certainly have made the vessels 2 inches less in depth, as the carrying capacity had remained intact. He did not think this would have improved matters—quite the contrary—besides, the wood deck with the wider stringer plate and a 14 × $\frac{10}{20}$ inch tie plate running fore and aft would count something, as adding to the longitudinal strength. Mr. Hök appeared to be dead against the well-deck type, with its dangerous break, and insisted upon a more efficient way of strengthening this break before comparing her with the other types. He did not think there was a great scope left for improvement in the strengthening of the break, as lately not only Lloyd's, but many builders have done all they could to compensate for this break of the main deck and he thought they had succeeded very well. He would advise Mr. Hök to leave the three-deck and spar-deck types to look after themselves for a while, devote his time to a careful study of the well-deck type of ship, and when he had fully solved the questions involved he was sure the Institution would be pleased to have placed before it the results of his investigations.

Some of the speakers had touched upon the question of light weights as given in the table. Well, since the well-decker treated in the paper was built about a year ago Lloyd's had increased some of the scantlings and other requirements considerably; in fact, the same vessels could not be built over again without allowing for at least thirty tons more material. This must be the well-known brook Mr. Courtier-Dutton was looking for, as Lloyd's seemed to increase their scantlings, etc., every now and then, and it is difficult to surmise where and when they intend to stop.

Mr. Thompson thought the freeboards of the three and spar-deck vessels might be less, while that in the well-deck was right. He would like to point out that the freeboard for each of the three types was an inch too much, and the vessels could be immersed another inch. This was done for convenience sake, as all the particulars of the well-decker referred to her, with 2 feet freeboard; whereas she actually sailed

with 1 foot 11 inches. He did not suppose this would materially affect the comparison, as the same applied to each of the three types.

In briefly summing up the different opinions by the various speakers, he could not help thinking most of them tended to favour the three and spar-deck types; though Mr. Macoll gave an incident of an awning-deck vessel carrying away her boats and other deck effects on several occasions, whereas a well-decker of the same dimensions behaved like a good child. This was not surprising as far as the awning-decker was concerned, considering her proportions; but he could not quite see how the well-decker managed to save her boats and similarly tempting targets for the seas, unless she managed to escape such bad weather as the awning-decker seemingly met with on several occassions.

He begged, in conclusion, to thank those present for the friendly and—but not least—instructive way in which they had shown their interest in the paper.

Note.—In reference to the graphical table of comparison (page 223) the figures on the bottom line of Plate XXXIII. correspond with those in the left hand column of the table of comparisons, and the vertical scales correspond with the three columns on the right, and denote 1 to 10,000 as the case may be.

DISCUSSION ON MR. BOYD'S PAPER ON THE "WEIGHT OF MACHINERY IN THE MERCANTILE MARINE."

The PRESIDENT said, that before beginning to take up the personal discussion, they had two contributions from members of the Institution —one from Mr. Blechynden and another from Mr. Hall-Brown. It had been their custom to read contributions of this nature, and he thought from the reputation and distinguished position of the two gentlemen whose names he had mentioned, they would be glad to have their views read by way of opening the discussion upon Mr. Boyd's paper.

The following communications were read by Mr. B. G. Nichol, for the Secretary :—

COMMUNICATION FROM MR. A. BLECHYNDEN.

In his paper on the "Weight of Machinery in the Mercantile Marine," Mr. Boyd has approached and dealt most ably with a subject which must be most interesting, not only to those engaged in the construction of ships and their propelling machinery, but to all interested in the mercantile marine.

As I take it, it is quite obvious that there must be great advantage in reducing the weight of marine machinery, so long as this can be done without crippling efficiency. The question for discussion appears to be the extent of that advantage, and how the reduction of weight is to be achieved.

Briefly the writer mentions two methods :—

1st. By change of design and material; and

2nd. By increasing the speed of revolutions.

Hitherto the first, viz., the adoption of the type of engine commonly used in the navy in place of the ordinary mercantile type has offered little temptation to shipowners, but rather the reverse, and its greater relative cost seems an effectual bar against its use, except in some very unusual cases; I shall therefore pass it by. But the second is apparently so advantageous that it is well worthy of thorough discussion.

Parenthetically, I observe that the writer speaks of "increase in piston speed" as "the greatest and most important factor in the problem of reducing the size and weight of engines." This is wrong. It is not piston speed, but speed of revolution. Speed of piston has nothing whatever to do with it excepting in so far as it may be affected by its factor revolutions per minute.

This is so obvious that it would be frivolous to refer to it, were the expressions not so commonly used, apparently as being synonymous and equal in value. Piston speed may be doubled by simply doubling the

stroke, the revolutions remaining the same. The result would be a considerably heavier engine with increased power—possibly an engine relatively heavier when compared with power than before: but, double the revolutions, and all else being the same, the power is doubled; and, as the weight remains the same, the weight relative to power is halved.

But to return to the consideration of the proposed means of reducing weight. I accept the figures for the weight of the basis engine as generally agreeing with average practice, but in stepping to the smaller engine I believe too great a reduction of weight has been made.

To concentrate ideas, let us extract the particulars of the basis and the reduced engine with natural draught from the table:—

Engine.	Cylinders.	Stroke.	Revolutions.	Weight.	Speed.	Less Weight.	Less Cost.
				Tons.			
Basis	23″, 37″, 60″	39″	75	256	9½	...	...
1st Reduced ...	21″, 34″, 55″	36″	95	218	9½	38 tons	£1,400

Now, the parts of the machinery whose weights should be reduced are as follows:—The engine *per se*, with its pumps (but not condenser), the shafting and appendages, the propeller, spare gear, tools, and some of the platforms about the engine. As the efficiency of the engine is to be maintained as before, I assume that it will be recognised that the condenser, its pipes and sea connections, and the steam pipes and other connections with the boilers, must remain as before. It must also be remembered that the cylinder ports, valves, etc., must be larger relatively to the cylinders, than in the basis engine, so that the cylinders of the reduced must be heavier relatively to their capacity than in the case of the basis engine. The shafting would also be reduced in weight only in proportion to its decreased area, its length would remain as before. Taking these matters into consideration, I estimate the reduction in weight for the smaller engines as not exceeding 20 tons, which calculation is substantiated by comparison with the details of engines actually made and weighed. Taking the reduction in cost *pro rata*, it is £740 instead of £1,400.

Even on this estimate it would, however, seem that the advantages of such an arrangement to the shipowner would be considerable, viz., a reduction of 20 tons in weight of machinery, and of £740 in cost and an annual gain of £120 for the extra 20 tons dead-weight capacity. These would be considerable advantages if realised.

Up to this point several advantages have been shown in favour of the lighter engine of *the same indicated horse-power*. But as the power is

developed for the purpose of propelling the vessel, it becomes necessary to carry the discussion a stage further before the problem is really solved.

It must be carried from the cylinders to the end of the propeller shaft. In short, we have not to compare these seeming advantages with the power developed in the cylinders at all, but with that proportion of it utilised in propelling the vessel.

This involves the consideration of a matter (*i.e.* the efficiency of the propeller) which has been characterised as a "collateral question which could only indirectly affect the main points." It is of no consequence whether it affects the main points directly or indirectly: it does affect them, and sometimes very seriously; therefore it demands consideration.

The writer has avoided this factor in the problem with the laudable object of narrowing the limits of argument, and gives his assurance that with suitable modifications in the propeller's design, the power would be used with equal efficiency in the case of the high as with the low speed engine. Notwithstanding this assurance, I must confess to having very grave doubts about it. It is unquestionably true that in some instances it would be possible to make such a modification in speed of revolution by altering the propeller's design without material loss, possibly with a gain of efficiency, but it altogether depends upon the stage from which the start is made. Unfortunately, the treatment of this part of the subject as an unimportant matter has led the writer to avoid giving the proportions of the basis engine's screw, so that it is impossible accurately to estimate the difference of efficiency in the two cases, and to assume a propeller is rather like setting up the proverbial man of straw; but from the general aspect of the case, I should expect the higher number of revolutions to be accompanied by a loss of efficiency, and it might not be uninteresting to show how very small a loss would entirely nullify the estimated gain.

I assume the following:—

I.H.P. of basis engine on voyage		1,150
Mean speed on voyage	knots per hour	9·15
Consumption of coal per I.H.P. per hour	lbs.	1·6
Length of voyage, one way	knots	3,500
Steaming time "	days	16
Vessel's actual steaming time per annum	days	224
Bunker coal will be carried for one way only.		
Average price of bunker coal put on board		15s.
Interest on capital, per cent. per annum	£5 0s.	20 per cent.
Insurance " "	£7 10s.	
Depreciation " "	£7 10s.	

Repairs assumed equal for the lighter high speed as for the heavier low speed engine.

It is taken as a fixed condition of the problem that the speed must be maintained constant, so that if any modification of the machinery decreases efficiency, some other changes must be made to ensure a higher indicated power, so that the power utilised in propulsion is maintained constant. Thus, indicated power must be increased in inverse proportion to the efficiency.

In making the calculation, the reduced engine of 21 in., 34 in., and 55 in. cylinders by 36 in. stroke, and boilers with 3,900 square feet heating surface, have been taken as the starting point, as it appeared the simpler method to work backwards, increasing size, weight, and cost of the machinery and the coal consumption in proportion to increased power.

Cost of machinery has been taken as proportionate to £1,400 for 38 tons throughout. This is not quite correct, as Mr. Boyd was dealing with engine alone, while we are now dealing with the whole machinery; it is, however, near enough for the purpose.

Efficiency is referred to the basis engine as a standard, not to absolute perfection; for example, 1 per cent. decrease means that the efficiency is 99 per cent. of the basis engine.

Table showing decrease of annual value to the shipowner for 1 per cent. decrease of efficiency; A on the assumption that the high speed engine is 218 tons weight; B that it is 236 tons weight or only 20 tons less than the basis.

		A	B
1—Increased weight of machinery	tons	2·18	2·36
2— „ „ of coal used per annum	„	44·2	44·2
3— „ „ „ when leaving port	„	3·157	3·157
4—Decreased dead-weight capacity (1 + 3)	„	5·337	5·517
5—Increased price of machinery		£80·4	87·00
6— „ cost of coal used per annum...		£33·15	33·15
7—Interest on increased price of machinery		£4·02	4·35
8—Insurance „ „ „		£6·03	6·425
9—Depreciation „ „ „		£6·03	6·425
10—Decreased freight		£32·022	33·102
11—Decreased annual value to shipowner (addition 6 to 10)		81·252	83·452

Now, compare the annual loss for decrease of efficiency with the estimated annual gain through decreased weight.

Under (A) we have £1,400 at 20 per cent. = £280.
And 38 tons dead-weight at £6 per ton = £228. Total £508.
This would be balanced by 6·252 per cent. decrease of efficency, *i.e.*, £81·252 × 6·252 = £508.

Compare with the condition (B).
We have £740 saving of price at 20 per cent. = £148.

And 20 tons dead-weight at £6 per ton = £120. Total £268. This would be balanced by 3·21 per cent. decrease in efficiency, *i.e.*, £83·452 × 3·21 = £267·88 per annum.

The figures assumed for the price of coal, insurance, depreciation, etc., may be a little in excess or defect of those actually obtaining; but they are sufficiently correct to show how small the decrease in efficiency need be to balance the estimated gain.

It must not be forgotten that there is the greater economy in the use of steam in the high speed engine to set against any probable loss of propulsive efficiency, but I should hardly expect this gain to go far as compensation.

Lack of time prevents my giving Mr. Boyd's other figures the attention which I should desire and they deserve, but I may point out that I also consider the decrease of weight (in the engine part at least) in the first case in the table overstated, and that the $\frac{3}{4}$ knot gain in speed in the cases of the last two in the table is about $\frac{1}{4}$ knot too much, assuming that the propellers have equal efficiency with the basis, and that the power varies with the cube of the speed. The calculation has evidently been made on the square of the speed.

These cases may also be affected by the variation of the propeller's efficiency so as to cause a reduction of even the remaining $\frac{1}{2}$ knot of supposed increase, but one is equally at a loss to judge of this as in the case of the smaller engine owing to want of information respecting the propelling instrument.

In fine, so far as the advantages estimated to be derived from the adoption of the smaller engine are concerned, I hold that the matter is enshrouded with the gravest doubt, and that though the last two may be better cases, they are, as I have pointed out, over estimated to the extent of at least $\frac{1}{4}$ knot.

So far as the principle of high speed of either piston or revolutions is involved, this itself should present little difficulty provided proper precautions are taken in the design and construction of the engines. Mr. Boyd has allowed for increase in bearings, etc.; there is, however, another increase which the cautious buyer ought to specify, viz., an increase in what is usually called the factor of safety referred to the statical basis.

It is evident that if the number of revolutions of a given engine are doubled the fatigue of the material due to shock must be also doubled in a given time. Similarly, if we go to higher piston speeds we increase the intensity of the shocks, if not their number, in a given time, and the

material is more rapidly fatigued and worn out, like poor humanity under similar treatment, and besides all this if an accident should happen with high speed it is calculated to be much more serious in its results than with low speeds. All this points to the necessity of a considerable increase in the safety factor. Those who have had most to do with high speed machinery know how important this is. Careful selection of material by test is also a *sine qua non.*

A. BLECHYNDEN.

COMMUNICATION FROM MR. E. HALL-BROWN.

DEAR MR. DUCKITT,—I am sorry I will be unable to be present at the discussion of Mr. Boyd's paper on Monday evening.

I would like to express the pleasure the reading of the paper gave me, and if in the following remarks I somewhat differ in opinion from Mr. Boyd, I am none the less indebted to him for the valuable information given in his paper.

I will not attempt to touch the boiler question; but will content myself with making a few remarks upon the alterations by which it is proposed to reduce the weight of the engines. There is no question whatever as to whether the average weight of engines in the mercantile marine can be reduced or not, as Mr. Boyd points out, it is merely a question of how far it will pay the merchant shipowner to do so.

What then are Mr. Boyd's proposals? They chiefly amount to an increase in the speed of revolution of the present type of engines.

At this point I would utter a protest at the loose way in which engineers speak of "piston speed." We find in the present paper this term is used to compare engines which may, for anything stated on the contrary, have had very different speeds of revolution. Now, I submit, that to compare piston speeds of various engines without regard to the speed of revolution is as good as making no comparison at all. At any rate such a comparison can have no bearing upon propulsive efficiency.

Mr. Boyd differs very greatly from the opinions expressed in the paper which I recently had the honour to read before this Institution. He points out that the engines which drove the screw in the ship "C" had only a piston speed of 422 feet per minute, which, he says was the practice ten years ago with two crank compound engines. Well, and if it was, what then? The speed of revolution of these engines was made as high as my firm considered would allow of the propeller working at or near its maximum efficiency. Mr. Boyd evidently considers this all

nonsense; he says he has obtained excellent results with a propeller running at 75 to 80 revolutions in engines with 39 inches stroke, and is of the opinion that this could be further increased. Now, will Mr. Boyd pardon me saying that all this has nothing whatever to do with the question? I have had excellent results with propellers running up to 85 revolutions with 48 inches stroke, and I know that this is exceeded every day, but *with very different type of boats from that mentioned in my paper.*

Since Mr. Boyd speaks of the excellent results he has obtained with 75 to 80 revolutions, let us take the case he gives, and which is his "basis." For convenience, I reproduce some of his figures:—

Length	310 feet.
Beam	40 feet.
Draught of water	22 feet.
Dead-weight	4,200 tons.
Speed	9½ knots on loaded trial.
I.H.P.	1,300.
Revolutions	75.

And if I take the displacement of the ship at 5,920 tons, which cannot be far from the mark, this gives a block coefficient of ·76 and the Admiralty coefficient—

$$\frac{V^3 D^{\frac{2}{3}}}{I.H.P.} = 216.$$

Now surely he does not consider 216 an excellent result for 9½ knots on loaded trial. I would consider it a very bad result indeed, and would at once try to find the cause, which, after all, *might* be the high speed of revolution.

Personally, I would undertake to drive this ship at 9½ knots easily with 300 I.H.P. less, if I were allowed to reduce the revolutions and to design the propeller, and I am convinced that there are many engineers who would do the same.

Now, if by increasing the revolutions from say 65 to 75, there is a loss of 300 I.H.P., equal to 4·8 tons of coal with a most economical engine, what does Mr. Boyd estimate the loss will be for a further increase of 20 or 25 per cent? I can only point out that at this rate it will *not* pay the shipowner to save weight by increasing the speed of revolution of the propeller.

Mr. Boyd seems to think that my conclusions regarding propeller efficiency are based upon Barnaby's experiments. This is not so. My

conclusions are based upon a pretty extensive experience with cargo boats, and although I used Barnaby's diagram as corroborative evidence, my conclusions must have been the same had the experiments referred to never been carried out.

I would like to have said something regarding the value of the weight gained, but this letter is already too long. One effect of Mr. Boyd's paper has been to confirm my opinion that economy does not lie in the direction of increased speed of revolution of propeller in cargo boats.

Yours faithfully,

E. HALL-BROWN.

Mr. B. G. NICHOL, in opening the discussion, said he thought the public would now be fully aware that the shipbuilders of this Institution had done their very utmost to show their desire to build structures which would carry either cargo or passengers from port to port in the shortest possible time, and had shown a great amount of ingenuity in the designs for the strength and stability of those structures. It was also certain that their engineers had shown that they were doing their very best to render their department as economical as possible in propelling those structures from port to port. There were many shipowners in the Institution, and he thought the time had now arrived for them to speak out, and explain what they considered the best type of ship to suit their interests, and they might depend upon it that both shipbuilders and engineers would be quick to meet their requirements. He thought no institution possessed more of the elements necessary to produce the most perfect ships than their own. With regard to the weights of engines, he left that to those who had had more recent experience than he had. With regard to the cargo carrying and insurance, he should leave that to the shipowners. But there was one point he should like very much to speak about, and that was probably the main reason why he had risen to his feet. Mr. Boyd, in his paper, treated the propeller, as Mr. Blechynden said, as a secondary matter, and he quite agreed with Mr. Boyd in doing so. He (Mr. Nichol) had estimated the proportions of the propeller which would drive that vessel at $9\frac{1}{2}$ knots speed with 75 revolutions a minute; he had also computed the proportions of the propeller which would absorb the whole power developed by the engines at 95 revolutions per minute, and drive the ship at exactly the same speed. The modified propeller was well within the limits of ordinary practice, and the efficiency exactly the same as that for 75 revolutions. He thought it unnecessary to give the figures worked out, as doubtless the members present had

ample data to enable them to make the comparison for themselves. Mr. Froude, probably the highest authority upon propelling instruments they had in England, had, as reference to the pages of the *Engineer* of May 9th would show, stated that the pitch ratio of the propeller might vary from ·8 to 2·5 and the same efficiency be maintained. He (Mr. Nichol) therefore fully agreed with Mr. Boyd in his efforts to diminish the weight of the propelling machinery in ships; and, subject to the limitation that he had expressed with regard to the bearing surfaces and to speeds of steam through the pipes and ports, he felt fully assured that ten years hence the speeds of revolutions of engines in their mercantile marine would as much exceed the work of to-day as the speeds of to-day exceeded those of ten years ago.

Mr. R. L. Weighton said he had not intended to enter into this discussion, but seeing that the President had called upon him, and that since he came into the room the contribution of Mr. Hall-Brown had been put into his hands, he had been drawn into it. Although he quite agreed with the general deductions Mr. Boyd had drawn, it just struck him there was still another way of comparing the different engines which were put down in the table at the end—a way which he thought brought out the results which follow a reduction in weight of engines, uncomplicated with other considerations. Mr. Boyd, in each case, it would be observed, compared engines which differed in price, that was to say, the standard normal engine had a certain price; the lighter engine was £1,500 higher, running at the same speed, then he took a smaller engine which run faster but was £1,400 cheaper. Now, suppose that instead of having this smaller engine normal—that was to say, of the usual design—they transferred it into the light design, it would cost just about the same as the larger normal engine of heavy design. Then suppose they went a step further and run this lighter engine at the speed Mr. Boyd run it at when normal, viz., 95 revolutions. They would be justified in doing this; more justified than Mr. Boyd was in the case of the heavy engine, for the moving parts were lighter, and therefore there would be less inertia, and less tear and wear, and less inconvenience from the higher speed. He would rather like to claim that the lightening of the engine, although carrying with it increased cost for given sizes of engines, also brought a certain advantage, inasmuch as they could run it faster without entailing those disadvantages entailed by running an ordinary engine faster. In connection with that, although Mr. Boyd had very rightly, and two or three times in his paper, mentioned that while he increased the speed

of revolution, the wearing surfaces must be increased, and the factor of safety must be kept constant; still, if this smaller normal engine runs faster, and the large one runs more than 75 revolutions, it will entail certain penalties. Those penalties are either increased tear and wear or increasing attention in upkeep, so that they must first of all expend more money in making larger bearing surfaces, etc., and better fitting engines altogether. Those penalties would be reduced if they adopted the light type of engine instead of the heavy, inasmuch as they took advantage of certain features the lighter engines have which enable them to be run faster with given wear and tear. The comparison would stand thus: Suppose they ran this engine (No. 2 in the table) at what Mr. Boyd ran it at, 95 revolutions, the weight instead of being 218 tons would be about 204 tons (he took Mr. Boyd's own figures as correct). So that they had here not only an increased speed of piston but also diminished weight to the extent of $256 - 204 = 52$ tons. This at £6 per ton gives a saving of $52 \times 6 =$ £312 per annum for engines of the same first cost, and what he (Mr. Weighton) would emphasise was that this gain (£312) was got not by increasing piston speed unjustifiably or without a reason, but by having lighter moving parts which justified them in running faster. Of course, as Mr. Boyd said, this paper was open to much friendly criticism, and it was in that spirit he put forward this comparison. With regard to the propeller question raised in Mr. Hall-Brown's communication, although there might probably be some reduction of efficiency in springing from 75 to 95 revolutions, still he would like to enter his protest against the very light and airy way in which Mr. Hall-Brown announces that he can drive this ship for 23 per cent. less power than it is driven here at 75 revolutions. He (Mr. Weighton) did not see how this was justified at all, and as Mr. Boyd's type ship seemed to him, when he first read the paper, in the light of certain particulars Mr. Boyd gave him, to have a fair efficiency, he was much surprised to find it with such a low coefficient as was given here, viz., 216.

Mr. R. Thompson—The displacement given by Mr. Hall-Brown was about 600 tons too light. It seemed as if Hartlepool always erred on the side of lightness. In this case the weight of the engine had been left out altogether. He had a similar ship of rather larger dimensions, carrying the same dead-weight—1,400 tons, and her gross displacement was 600 tons more than that given by Mr. Hall-Brown.

Mr. Weighton thought there must be some mistake, but what he wanted to emphasise was this, that in the paper on "High Speed Engines

for Cargo Boats," Mr. Hall-Brown certainly claimed Mr. Barnaby's deductions as supporting his conclusions, and he left the impression that he took Mr. Barnaby's methods as well as his conclusions as correct, and argued from them that by his diagrams he could tell the efficiency due to revolutions. Now, he said here that he did not base his calculations on Mr. Barnaby's methods at all. Mr. Barnaby assumes all through his treatise, and Mr. Hall-Brown inferentially, the following:—

$$R \propto S$$

$$D \propto \frac{1}{\sqrt{S^3}}$$

$$D \propto \sqrt{I.H.P.}$$

These were some of the principles in accordance with which Mr. Barnaby jumps from propellers 9 inches diameter up to propellers of 20 feet diameter, or up to any size, and in accordance with which he descends from 600 revolutions to 60 revolutions. Now, he demurred to the assumption tacitly underlying all deductions based upon such principles until at least it was proved satisfactorily that the above relations held good for all speeds and all sizes and types.

Mr. R. Thompson was very glad, indeed, that Mr. Boyd had taken up the subject of the weight of engines. It was one intimately connected with their trade, and while they had had a discussion as to types of vessels, it was a very appropriate following, the weights of engines. On the subject of cost, these last five or six years much had been done both by shipbuilders and engineers to further the interests of the shipowners of this country by the various discussions that had taken place in this Institution, and he thought this paper one bearing upon those points upon which, probably, they would have to make some change. There was no doubt in his mind that they were rapidly coming to the time when the revolutions of engines and the weight of engines would be improved, and he thought improved by a higher rate in the number of revolutions and by a lighter engine. They would have to be careful not to get on to the light side, but to see that the margin and factor of safety be enough to ensure a good working engine and give better economical results than at present. With regard to Mr. Weighton's remarks as to the small amount of displacement given by Mr. Hall-Brown, he knew that it would take 600 tons more displacement to give the tons dead-weight named. It was much too light a weight for a ship of that size. He hoped that the discussion would set them all thinking, and from the results of that meeting there would spring some

improvement in machinery. They had got the triple expansion engine, but it might be in another direction, such as the present paper suggested.

Mr. G. E. MACARTHY said that what he wanted to bring to Mr. Boyd's notice was, in substance, contained in Mr. Blechynden's communication, but he wished to deal with the subject more especially from the shipowner's point of view. In Mr. Thompson's paper, to which the writer of the present paper has alluded, he (Mr. Macarthy) was quoted as stating that the working expenses of the steamer, excluding the bunker coals, but including 5 per cent. for depreciation, would amount to £15 per day. Mr. Thompson very correctly pointed out, however, that he (Mr. Macarthy) had not taken the question of profit into account. Profit was a very indefinite and unstable element to deal with, sometimes it had to be taken as below zero, but he thought a fair estimate might be £5 per day; that would make £20 saved. But he was dealing with a smaller steamer than that taken as the type in this paper, and at least another £3 must be put on; therefore, instead of the £15 per day, which was the basis of calculation in the paper, it should be £23 per day, and this altered the calculations very materially in favour of the lighter engines, or rather, the faster engines. The light engines, which were taken at the increased cost of £1,500, giving a saving of 16 tons, were very properly put on one side, as it was quite evident a saving of £96 per annum was quite inadequate to the extra expenditure of £1,500; the insurance alone would be more. The smaller engines, described as normal, at an increased cost of £400, were worked out in the paper as showing an extra cost per annum of £1,040, against which there was a saving of 18 days. On his calculation of £23 a day, that gave £414 per annum, but in the paper there was no calculation of the loss of freight which would occur through the extra coals necessarily carried, which was estimated at 880 tons per annum in obtaining this increased speed, and that would result in a loss of freight, which would very materially affect the result against the engines. Therefore he came, as a shipowner, to the small engines which stand in the tables:—"Natural draught, normal engines of 21 inch, 34 inch, 55 inch, and 56 inch stroke," and so on, running at the same speed as the basis vessel, and showing a saving in cost of £1,400. Well, that was an exceedingly pleasing thing for the shipowner, and if he, as a shipowner, could be assured that such engines could be run with safety, he for one would like to see a vessel so fitted. Working out the figures of the two types of engines given in the writer's tables, he (Mr. Macarthy) came to the same conclusions on the question of speed *versus* consumption that he had arrived at in considering Mr. Thompson's paper, viz.:—

Normal engines, with natural draught, 23 inch, 37 inch, 60 inch × 39 inch stroke, 4,650 feet heating surface, 90 revolutions, 276 tons weight, 10¼ knots speed. £400 extra cost.

Dr.		
Interest and depreciation on £400 at 10 per cent. per annum ...	£40	
Cost of 880 tons extra fuel, at 20s. per ton	880	
Loss of cargo capacity on 20 tons extra weight, at £6	120	
Loss of cargo capacity by extra fuel, 4 tons per day, equal to 110 tons, at £6 per annum	660	
		£1,700
Less—		
18 days' time saved, at £23	£414	
18 days' fuel saved, say at 22 tons = 396 tons, at 20s.	396	
		810
Loss per annum		£890

N.B.—In addition, there would be a loss of bunker space through the increased size of boilers.

Normal engines, with natural draught, 21 inch, 34 inch, 55 inch × 36 inch stroke, 3,900 feet heating surface, 95 revolutions, 218 tons weight, 9½ knots speed. £1,400 less cost.

Cr.		
38 tons saved in cargo capacity, at £6	£228	
Interest, depreciation, insurance, etc., on £1,400, at 20 per cent....	280	
Profit per annum		£508

Mr. Boyd, in rising to reply to the discussion, said he should not detain them many minutes. This was the last meeting of the session, and as the closing formal business had to be gone through he would be as brief as possible. Both Mr. Blechynden and Mr. Hall-Brown had criticised the expression "piston speed." Well, no doubt there was a certain truth and value in their criticism. The expression had a certain looseness about it if it was applied too widely; but he would point out that at any rate in the lowest four examples the stroke remains the same, 39 inches, and therefore the expression "piston speed" might be taken as fairly synonymous with the speed of revolutions. At any rate, he did not feel that the strokes under discussion varied to such an extent as to make this expression inaccurate or irregular. He confessed it would have been better if in the body of the paper the words "piston speed" had been accompanied by the words, "increase of revolutions." That the increase in the number of revolutions was regarded as one of the factors with which they had to deal was plainly shown in the tables at the end, in which the number of revolutions were given as well as the piston speed, and were tabulated from 75 to 95 as the case might be.

Another point alluded to in the remarks made by these gentlemen was the question of propeller efficiency. Now, of course, this was a very important point, and probably the weakest point in the paper; but he must say he did not omit it from any want of thought,

or recognition of the importance it had upon the subject; but he did not know whether other gentlemen had felt the same, but at any rate he felt in attempting to write a paper of this kind, the enormous difficulty of concentrating the considerations which had to be weighed on one side and another into limits which could be grasped by ordinary engineers, such as he himself professed to be, and it was with the view of eliminating as far as possible considerations that he thought did not primarily affect the weight of the engines, that he to a great extent omitted the consideration of the propeller efficiency. He might say that these calculations were based upon the results which his firm had obtained from five or six vessels they had engined of precisely the dimensions given in the paper, they were all of the same size, and all tried under precisely similar conditions, and in one or two cases with the increased or reduced number of revolutions given in the paper, and they found that the degrees of efficiency of the propeller, or in other words the alteration in propeller efficiency between the revolutions mentioned for $9\frac{1}{2}$ and $10\frac{1}{4}$ knots was such that he thought they might fairly be omitted from the present consideration.

For example, his company had lately an opportunity of making a series of progressive runs with a vessel of slightly smaller dimensions than the normal vessel described in his paper, and the speeds obtained were $6\frac{3}{4}$, $9\frac{1}{4}$, $10\frac{1}{4}$, and 11 knots. The propeller was designed for $9\frac{1}{4}$ knots, and the propeller efficiency was therefore greatest at that speed, but as between $9\frac{1}{4}$ and $10\frac{1}{4}$ knots the increase in slip was only 2·19 per cent. The slip increased considerably when a speed of 11 knots was reached, but he held to his opinion that the increase in the speed of revolutions advocated in the paper might be easily used without a greater loss of propeller efficiency than could be compensated for in modification in propeller design. At the same time, it must not be understood that he did not fully admit the criticism of these gentlemen that propeller efficiency was a most important factor in the calculations of the sizes of the engines. He need not say he was extremely pleased to hear the remarks which fell from his friend Mr. Nichol, who was a much better scientist than he himself professed to be, and which, he thought, fairly confirmed the position he had taken up in the paper.

One other point he wished to allude to was the question of the indicated horse-power in respect to the increase of speed from $9\frac{1}{2}$ to $10\frac{1}{4}$ knots. He must confess that this was just an example to him which he had not appreciated before, of how necessary it was in compiling figures of this sort to follow the accurate figures which presented themselves,

and not attempt to put them into "round figures." He found the state of the case was that 10¼ knots required 1,550 indicated horse-power, but there was a slight inaccuracy in the indicated horse-power for 9½ knots, instead of 1,300 it should be 1,269; 31 indicated horse-power made all the difference, and if those tables were corrected with that alteration in power, it would be found that the power came out very nearly as the cube of the speed. But he hardly felt justified in speaking very strongly on that point. He had in his office a number of results obtained from a great number of vessels in which the rule of the cube of the speed did not hold good universally, and he thought it could not be held that this proportion was applicable without variations either in one direction or another. The information in his possession pointed that there were variations both above and below it, and although the figures given in the paper might not be strictly accurate within a few decimal points, the main results may be fairly accepted.

He would say a word or two in reply to Mr. Hall-Brown. That gentleman was scarcely accurate in the coefficient given in his memorandum. Taking the actual displacement of the ship, and the power and speed obtained on the trial trip, a coefficient of about 240 was the result. At the same time he begged also to dissent most emphatically from the statement made by Mr. Hall-Brown that it was within the power of "many engineers" to drive a vessel of the dimensions given at a speed of 9·5 knots on 1,000 indicated horse-power. He did not believe it was possible, and in this view he was confirmed by the remark of Mr. Weighton—at any rate he frankly admitted that such a result would be superior to anything hitherto acccomplished by his own firm.

With regard to the weight of the engines, Mr. Weighton's suggestion offered no doubt a very tempting proposal. If Mr. Weighton saw the original tables made out in his office, he would see upon them the type of engine he named; but it was omitted from the paper, and the calculations given at the end, from the simple desire to keep the communication as simple and easily understandable as possible. With regard to what Mr. Macarthy said about the value to the shipowner, he very soon found he was getting out of his depth here; but he thought he had cleverly covered himself by saying that the shipowners would be the best to appreciate the value of any saving this would be, and he was quite sure the Institution was very much indebted to Mr. Macarthy for the way in which he had put it.

The PRESIDENT said their time was getting very short. He begged to move a hearty vote of thanks to Mr. Boyd for his very valuable paper.

The motion was cordially accepted.